





## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<b>(21) International Application Number:</b> PCT/US99/30707 <b>(22) International Filing Date:</b> 22 December 1999 (22.12.99) <b>(30) Priority Data:</b> 60/113,204 22 December 1998 (22.12.98) US <b>(63) Related by Continuation (CON) or Continuation-in-Part (CIP) to Earlier Application</b> US 60/113,204 (CON) Filed on 22 December 1998 (22.12.98) <b>(71) Applicant (for all designated States except US):</b> BOARD OF REGENTS, THE UNIVERSITY OF TEXAS SYSTEM [US/US]; 201 West 7th Street, Austin, TX 78701 (US). <b>(72) Inventors; and</b> <b>(75) Inventors/Applicants (for US only):</b> MASTERS, Bettie, Sue, S. [US/US]; 16534 Hidden View, San Antonio, TX 78232 (US). MARTASEK, Pavel [CZ/US]; 7531 Pipers Lane, San Antonio, TX 78251 (US). ROMAN, Linda, J. [US/US]; 2814 Squaw Creek, San Antonio, TX 78230 (US). KRAL, Vladimir [CZ/CZ]; Na Kozacce 8/9275, 120 00 Praha 1 (CZ). POULOS, Thomas, L. [US/US]; 48 Urey Court, Irvine, CA 92612 (US). RAMAN, C., S. [-/-]; - (**).		<b>(74) Agent:</b> WILSON, Mark, B.; Fulbright & Jaworski L.L.P., 600 Congress Avenue, Suite 2400, Austin, TX 78701 (US). <b>(81) Designated States:</b> AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG). <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>
<b>(54) Title:</b> STRUCTURAL BASIS FOR PTERIN FUNCTION IN NITRIC OXIDE SYNTHASE <b>(57) Abstract</b> <p>This invention describes methods and elucidates the three dimensional structure of nitric oxide synthase and its variants. Also described are methods of structural analysis to determine the binding of pterin to endothelial nitric oxide synthase and methods for screening and identifying small molecule modulators of endothelial nitric oxide synthase proteins and their variants. The invention also describes methods for identifying drugs that modulate nitric oxide synthase and its variants and are effective against diseased states in which NO signaling is defective or insufficient.</p> <div style="display: flex; justify-content: space-around; align-items: center;">   </div>		

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## STRUCTURAL BASIS FOR PTERIN FUNCTION IN NITRIC OXIDE SYNTHASE

The government owns rights in the present invention pursuant to grant numbers  
5 GM 32688, GM 52419 and HL 30050 from the National Institutes of Health.

**1. Field of the Invention**

The present invention relates generally to the fields of protein structure and  
crystallography. More particularly, it concerns the three dimensional structure of nitric  
10 oxide synthase.

**2. Description of Related Art**

Nitric oxide ( $\text{NO}^\bullet$ ), a free radical, is an ubiquitous signaling molecule which  
participates in diverse cellular processes, including regulation of blood pressure,  
15 neurotransmission, and the immune response (Dinerman *et al.*, 1993).

$\text{NO}$ , is well recognized as having various biologically relevant activities. For  
example,  $\text{NO}$  activates soluble guanylate cyclase in vascular smooth muscle cells which  
in turn increase cyclic guanosine monophosphate (cGMP) resulting in vasorelaxation,  
20 (Waldman *et al.*, 1987) and ultimately leads to vasodilation and a reduction in blood  
pressure. It is well established that the NOS family of enzymes form nitric oxide from L-  
arginine, and the  $\text{NO}$  produced is responsible for the endothelium dependent relaxation  
and activation of soluble guanylate cyclase, neurotransmission in the central and  
peripheral nervous systems, and activated macrophage cytotoxicity (Sessa, William C.,  
25 1994).

$\text{NO}^\bullet$  production is tightly regulated by nitric oxide synthases (NOS), a family of  
enzymes of which three genetically encoded isoforms have been identified (Knowles and  
Moncada, 1994; Marietta, 1993; Masters *et al.*, 1996). The neuronal (nNOS) and  
30 endothelial NOS (eNOS) are constitutive with post-translational regulation of enzyme

activity. The inducible isoform (iNOS) is regulated mostly at the level of transcription.<sup>3</sup> All three isoforms of NOS oxidize L-arginine to L-citrulline and NO.

Each NOS isoform consists of a heme domain linked via a calmodulin binding  
5 linker peptide to a P450 reductase-like diflavin domain giving a large polypeptide (130  
kDa - 160 kDa). Only dimeric NOS is catalytically active. Upon  $\text{Ca}^{2+}$ /calmodulin  
binding, the FAD of the reductase domain transfers reducing equivalents from NADPH  
to FMN, which in turn, reduces the heme iron. Reduction of the heme iron leads to  $\text{O}_2$   
activation followed by oxidation of a L-Arg guanidino N atom to  $\text{NO}^\circ$  and L-citrulline.  
10 All three NOS isoforms exhibit an absolute requirement for tetrahydrobiopterin, (referred  
to as  $\text{BH}_4$ ), as a cofactor to function (Tayeh and Marietta, 1989; Kwon *et al.*, 1989), but  
the precise role it plays has remained elusive (Hemmens and Mayer, 1997).

Due to the linking of the heme and flavin domains, the various NOS isoforms are  
15 large and range in size from 130 to 160 kDa. The N-terminal domain of NOS contains  
the heme active center where L-arginine and  $\text{BH}_4$  bind. While the flavin reductase  
domain is similar in sequence to the P450 reductase, the NOS heme domain bears little  
resemblance in sequence to P450s even though the NOS heme domain exhibits  
characteristics strikingly similar to those of cytochrome P450 monooxygenases.

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Recently, the structures of mouse iNOS heme domains and cytochrome P450  
reductase have both been determined (Crane and Trainer, 1997; Wang *et al.*, 1997). In  
both of these studies, short versions of the full length iNOS were used. For iNOS, the  
heme domain consisting of residues 115-498 was used, whereas for P450 reductase the  
25 soluble fragment (amino acids 57-676) was used. These investigations revealed that the  
flavin domain of P450 reductase is structurally similar to flavodoxins while the FAD-  
NADPH domain is structurally homologous to ferredoxin reductase. Additionally, a  
linker domain connects the FMN and FAD domains. The flavins are only 4Å apart which  
blocks the edge of FMN that would normally be exposed in flavodoxins.

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Despite the extensive characterization of the heme domain of iNOS, little is known about the structure of eNOS or the BH<sub>4</sub> binding domain therein. To understand the basis for the obligatory pterin cofactor requirement in catalysis and structure, there is a need to solve the structure of the eNOS heme domain, both in the presence and absence of BH<sub>4</sub>. Such findings will have major implications in drug discovery and mechanisms of action of the proteins.

### SUMMARY OF THE INVENTION

To overcome the limitations of the art the present inventors have developed methods for the structural analysis of endothelial nitric oxide synthase. In one embodiment the method comprises: a) subcloning a gene encoding the endothelial nitric oxide synthase in an expression vector; b) obtaining expression of the endothelial nitric oxide synthase protein from the vector; c) purifying the endothelial nitric oxide synthase protein; d) preparing an endothelial nitric oxide synthase protein sample amenable for crystallization; e) crystallizing the endothelial nitric oxide synthase protein sample; and f) performing a three-dimensional structural analysis of the endothelial nitric oxide synthase by x-ray crystallography.

In one embodiment, the endothelial nitric oxide synthase protein expressed is a variant endothelial nitric oxide synthase protein. In one aspect of the method, the crystallizing comprises practicing a sitting drop vapor-diffusion method. To compare the crystal structures in the presence and absence of tetrahydrobiopterin, in one embodiment, the crystallizing is performed in the presence of tetrahydrobiopterin while in another embodiment, the crystallizing is performed in the absence of tetrahydrobiopterin. In a further embodiment the crystal structures are determined by performing x-ray crystallography on the endothelial nitric oxide synthase protein crystallized both in the presence and in the absence of tetrahydrobiopterin.

The invention also describes a method of structural analysis to determine the binding of pterin to endothelial nitric oxide synthase that comprises: a) determining the

crystal structure of a dimeric heme domain of the endothelial nitric oxide synthase in the presence of the pterin; and b) determining the crystal structure of a dimeric heme domain of the endothelial nitric oxide synthase in the absence of the pterin; and comparing the crystal structures. In one embodiment the pterin is tetrahydrobiopterin. In a specific  
5 embodiment, the tetrahydrobiopterin is (1'R,2'S,6R)-5,6,7,8-tetrahydrobiopterin. In one aspect, the crystal structure is determined at a resolution of between about 1.9 Å to about 2.1 Å.

The invention also describes methods for screening and identifying small  
10 molecule modulators of endothelial nitric oxide synthase proteins comprising: a) providing a pterin-free endothelial nitric oxide synthase structure; b) screening the small molecule modulators for their ability to bind to a pterin-binding site of the endothelial nitric oxide synthase ; and c) performing assays to determine the ability of the small molecule modulators to modulate the activity of endothelial nitric oxide synthase. A  
15 modulator is defined herein as a molecule that is capable of activating or inhibiting the activity of endothelial nitric oxide synthase. The molecule can be a small molecule.

In one embodiment, the small molecule modulator inhibits endothelial nitric oxide synthase. In another embodiment, the small molecule modulator activates endothelial  
20 nitric oxide synthase. In one embodiment, the endothelial nitric oxide synthase protein expressed is a variant endothelial nitric oxide synthase protein. In another embodiment, the pterin is tetrahydrobiopterin. In a specific embodiment, the tetrahydrobiopterin is (1'R,2'S,6R)-5,6,7,8-tetrahydrobiopterin.

In one aspect of the method, the small molecule modulators are molecules and  
25 chemical-fragments from chemical-fragment libraries. In another aspect, the screening is performed by computerized methods. In yet another aspect of the method, the assays to determine the activity of endothelial nitric oxide synthase are performed *in vitro* or *in vivo*.

In another embodiment, the invention describes methods for identifying drugs against diseased states in which nitric oxide signaling is defective or insufficient comprising: a) providing a tetrahydrobiopterin-free endothelial nitric oxide synthase structure; b) screening the drugs for their ability to bind the tetrahydrobiopterin binding site; and c) performing assays to determine the ability of the drugs to activate the endothelial nitric oxide synthase. The diseased states include but are not limited to conditions wherein defective or insufficient nitric oxide signaling leads to impaired neurotransmission; impaired insulin release; impaired penile erection; impaired vasorelaxation; and impaired oxygen detection.

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The invention also provides endothelial nitric oxide synthase structure, obtained by the process comprising: a) subcloning a gene encoding the endothelial nitric oxide synthase in an expression vector; b) obtaining expression of the endothelial nitric oxide synthase protein from the vector; c) purifying the endothelial nitric oxide synthase protein; d) preparing an endothelial nitric oxide synthase protein sample amenable for crystallization; e) crystallizing the endothelial nitric oxide synthase protein sample; and f) performing a three-dimensional structural analysis of the endothelial nitric oxide synthase by x-ray crystallography. The structure of the endothelial nitric oxide synthase is described in the specification.

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The invention also provides methods for screening and identifying a candidate substance with the ability to inhibit endothelial nitric oxide synthase comprising: a) obtaining a cell with endothelial nitric oxide synthase activity; b) admixing the candidate substance with the cell; and c) determining the ability of the candidate substance to inhibit the endothelial nitric oxide synthase activity of the cell.

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The invention further provides a method for screening and identifying a candidate substance with the ability to inhibit endothelial nitric oxide synthase comprising: a) obtaining a purified endothelial nitric oxide synthase; b) admixing the endothelial nitric oxide synthase with the candidate substance; and c) performing X-ray crystallography analysis to determine the binding of the candidate substance.

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A" or "an" is defined herein to mean "at least one" when used in combination with the term "comprising" in the specification and claims.

5 Other objects, features and advantages of the present invention will become apparent from the following detailed description. It should be understood, however, that the detailed description and the specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become  
10 apparent to those skilled in the art from this detailed description.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

The following drawings form part of the present specification and are included to  
15 further demonstrate certain aspects of the present invention. The invention may be better understood by reference to one or more of these drawings in combination with the detailed description of specific embodiments presented herein.

**FIG. 1.** Panel A, schematic representation of the eNOS heme domain  
20 dimer viewed perpendicular to the dyed axis of symmetry. The two  $\text{BH}_4$  molecules are shown as yellow space-filled models. The zinc located along the dyed axis of symmetry is highlighted as a red ball and labeled. Panel B, molecular surface map of the electrostatic potential of the eNOS heme domain dimer calculated using GRASP. The blue and red contours represent positive and negative potential, respectively. Fully  
25 saturated color indicates a potential of 5 kT. This view is rotated  $90^\circ$  from the orientation shown in Panel A such that the viewer is looking toward the  $\text{ZnS}_4$  center directly along the two-fold relating the monomers. The surface surrounding the  $\text{ZnS}_4$  is the most extensive electropositive region on the dimer and could provide an electrostatic docking site for the FMN/FAD reductase. This could enable the electron donors (FMN domains  
30 of the reductase) to approach close to the  $\text{ZnS}_4$  center thereby providing a conduit to



either/both pterin and heme groups. Interestingly, both Mss4 and LIM proteins utilize ZnS<sub>4</sub> containing surfaces to mediate protein-protein interaction (Yu and Schreiber, 1995; Rabbits and Boehm, 1990; Schmeichel and Beckerle, 1994).

5           **FIG. 2.**       Stereo view of the 2Fo-Fc 1.9 Å omit electron density map around the ZnS<sub>4</sub> center. The map was obtained from model phases after a round of simulated annealing with the atoms shown excluded from the refinement. The map is contoured at 1σ (blue) and 10σ (black). The zinc ion was identified using anomalous dispersion effects characteristics for the metal. X-ray wavelengths of 1.280 Å and 1.286 Å (zinc  
10 absorption edge, λ = 1.283 Å) were chosen using a tunable synchrotron X-ray source. Zinc exhibits significant anomalous scattering effects at 1.280 Å with little anomalous scattering contribution at 1.286 Å. Heme Fe exhibits some anomalous scattering at both wavelengths (iron absorption edge, λ = 1.739 Å). Direct methods (Sheldrick, 1997) were also used to independently confirm the location of the metal center. The cysteine  
15 residues of eNOS involved in zinc coordination are strictly conserved in all NOS sequences known to date indicating that the metal center is a common feature in all NOS isoforms. The ligands, Cys 96 and Cys 101, are part of a small 3-stranded antiparallel β-sheet (2 strands from one monomer and 1 strand from the other) that orients Cys 96 and Cys 101 in the same direction directly across antiparallel strands. In addition to β-strand  
20 main chain H-bonds, Sy (96) and Sy (101) form H-bonds with the peptide NH of residues 102 and 103, respectively. Crane *et al.* (1998) interpreted this region in iNOS as an inter-subunit disulfide bond between symmetry related Cys 109 residues which corresponds to one of the ligands in eNOS, Cys 101. The reason for the discrepancy is not clear. However, the iNOS heme domain dimer structure was solved at medium  
25 resolution (2.6 Å) and Crane *et al.* (1998) noted a disordering in residues 101-107 immediately preceding Cys 109. Considering the strongly reducing conditions in the cytosol, the formation of a disulfide would be both kinetically and thermodynamically disfavored (Braakman *et al.*, 1994). Hence, the inventors conclude that the loss of zinc in the iNOS structure led to the disordering of the polypeptide chain. ZnS<sub>4</sub> centers have  
30 been observed in four other enzymes where they play a structural role (Lipscomb and Sträter, 1996; Tsukihara *et al.*, 1995; Vallee and Auld, 1993). In *E. coli* Ada protein a

catalytic function of  $\text{ZnS}_4$  has been demonstrated (Lipscomb and Sträter, 1996; Tsukihara *et al.*, 1995; Vallee and Auld, 1993).

**FIG. 3.** Comparison of the pterin-free and -bound structures at  $\text{BH}_4$  binding site. L-Arg was found in the  $\text{BH}_4$  binding pocket in one subunit whereas only glycerol and water molecules could be modeled in the other subunit. Panels A and B are the 2Fo-Fc omit electron density maps contoured at  $1\sigma$  with arginine or glycerol excluded in the calculation, respectively. Side chains of the same color belong to the same monomer. Panel C shows  $\text{BH}_4$  being sandwiched between Trp 449 of the same subunit (green) and Phe 462 from the other (cyan). Among the extensive H-bonding interactions of  $\text{BH}_4$  to protein, two crucial ones are between N at position 3 of the pterin ring and a heme propionate, and between the OH in dihydroxypropyl side chain of  $\text{BH}_4$  and Ser104 carbonyl oxygen. These interactions are closely mimicked by L-arginine with its guanidino nitrogen and primary amino group, respectively, as depicted in panel D. In addition, a new water molecule in panel D satisfies the H-bonding interactions of the  $\text{BH}_4$  amino group. Therefore, L-Arg in the  $\text{BH}_4$  site is able to closely mimic the H-bonding and aromatic stacking interactions in the  $\text{BH}_4$  complex. The structure of the  $\text{BH}_4$  complex in panel C has L-Arg bound in the heme pocket while in panel D, the inhibitor, SEITU, is in the heme pocket. The protein structure of the inhibitor and substrate complexes are essentially identical. In addition, the structure of the substrate or inhibitor complex with  $\text{BH}_4$  bound exhibit no differences at the  $\text{BH}_4$  site.

**FIG. 4.** The  $\text{ZnS}_4$  center and its relation to  $\text{BH}_4$ . The metal ion (white ball) is equidistant from each  $\text{BH}_4$ , a distance of 12 Å. The peptide carbonyl oxygen of Ser 104 H-bonds with one  $\text{BH}_4$  OH group.  $\text{ZnS}_4$  plays an effector role in helping to form and stabilize the pterin binding pocket which, in turn, promotes substrate binding. Therefore, the  $\text{ZnS}_4$  center,  $\text{BH}_4$ , and substrate are all structurally linked at the dimer interface. Both the zinc atom and its cysteine ligands are accessible to solvent.

**FIG. 5.** The proposed mechanism for pterin radical formation in NOS catalysis. I- $\text{BH}_4$  showing the ring numbering scheme. The pKa of N3 is near 10.6. II-

BH<sub>4</sub> mono cation form and III the BH<sub>4</sub><sup>++</sup> radical, respectively. The inventors are proposing that NOS is designed to stabilize III, the radical cation. Stabilization of aromatic cation radicals is reminiscent of cytochrome c peroxidase which is designed to stabilize a cationic Trp radical essential for catalysis (Sivaraja *et al.*, 1989; Houseman *et al.*, 1993).

### DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

NO is a key intracellular signal and defensive cytotoxin in the nervous, muscular, cardiovascular, and immune systems (Moncada and Higgs, 1993; Schmidt and Walter, 1994; Nathan, 1997; Christopherson and Bredt, 1997; Marletta, 1993; Mayer and Werner, 1995; Masters *et al.*, 1996; Steuhr *et al.*, 1997). eNOS produces low NO concentrations for neurotransmission, insulin release, penile erection, vasorelaxation, oxygen detection, and the like. Since NO was voted the molecule of the year by *Science* in 1992, there has been a tremendous amount of work on the pharmacological properties of this molecule. Despite all these studies, little is known about the structure of eNOS. Once the structural determination of eNOS has been made, designing agents to potentiate or inhibit the action of NO becomes a realizable goal. The present invention is directed to addressing these needs.

#### **A. The Present Invention**

The present invention describes the crystal structure of the dimeric heme domain of endothelial nitric oxide synthase (eNOS). This structure was determined both in the presence and absence of (1'R,2'S,6R)-5,6,7,8-tetrahydrobiopterin (BH<sub>4</sub>) to understand its role as an indispensable cofactor in nitric oxide biosynthesis. The BH<sub>4</sub> bound structure at 1.9 Å reveals a novel zinc tetrathiolate (ZnS<sub>4</sub>) sandwiched at the dimer interface which functions by maintaining the integrity of the pterin and substrate binding sites. The pterin-free structure at 2.1 Å unambiguously establishes an obligatory function for BH<sub>4</sub> in catalysis and rules out a role in the dimerization process. These structures suggest a reaction mechanism that involves a pterin radical. The unusual finding that an L-arginine (L-Arg) is bound at the BH<sub>4</sub> site in the pterin-free structure suggests evolution of cofactor

recognition from a common L-Arg-binding ancestor in the primordial NOS catalytic machinery.

Here the inventors report the 1.9 Å crystal structure of the dimeric heme domain of constitutive eNOS (Table 1), which maintains the catalytic site for NO<sup>•</sup> synthesis. The overall fold of the bovine eNOS heme domain (FIG. 1) is similar to that reported for the 2.6 Å structure of the iNOS heme domain dimer (Crane *et al.*, 1998). eNOS belongs to the α/β protein class and the quaternary structure is characterized by a tightly packed dimer interface which buries 3000 Å<sup>2</sup> per subunit of solvent accessible surface (55% hydrophobic and 45% polar).

To understand the basis for the obligatory pterin cofactor requirement in catalysis and structure, the inventors have solved the structure of eNOS heme domain both in the presence and absence of BH<sub>4</sub> resulting in three major structural findings. First, the inventors have found a novel ZnS<sub>4</sub> center (in both pterin-bound and -free structures) located at the bottom of the dimer interface (FIG. 1) with the metal tetrahedrally coordinated by two pairs of symmetry-related cysteine residues (FIG. 2) from each subunit. BH<sub>4</sub> H-bonds directly with a heme propionate which also entertains H-bonds with the substrate, L-Arg (FIG. 3C). The zinc is positioned equidistant from each heme (21.6 Å) with one of its ligands, Cys 101, separated by only two residues from Ser 104 which H-bonds directly to BH<sub>4</sub> (FIG. 4). In addition, Val 105 forms a direct nonbonded contact with BH<sub>4</sub>. Therefore, disruption of the metal center either by demetallation or ligand removal via mutagenesis will distort this region of the polypeptide chain resulting in greatly diminished affinity for BH<sub>4</sub>. Since BH<sub>4</sub> couples directly to the heme, alterations at the pterin site will in turn affect the heme pocket and L-Arg binding. A number of studies (Chen *et al.*, 1995; Rodríguez-Crespo *et al.*, 1997; Ghosh *et al.*, 1997; Venema *et al.*, 1997; Miller *et al.*, 1997) confirm the dramatic loss in protein stability, catalytic activity, and BH<sub>4</sub> binding upon removal of Cys 96 and/or Cys 101 in eNOS or their counterparts in the inducible and neuronal isoforms.

The identification of the new  $\text{ZnS}_4$  center in NOS unambiguously establishes the structural role played by these cysteine residues in forming and maintaining the integrity of the pterin site. The inventors' finding of zinc in eNOS has pathophysiological implications as well. Inherited vascular dysfunction may arise from mutations that specifically weaken zinc affinity resulting in a dysfunctional eNOS. For example, in familial amyotrophic lateral sclerosis (ALS), over 50 independent mutations in Cu/Zn-superoxide dismutase give rise to a common toxic phenotype invariably characterized by decreased zinc affinity up to 100,000 fold (Lyons *et al.*, 1996; Crow *et al.*, 1997).

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Second, in the absence of  $\text{BH}_4$ , the overall eNOS heme domain structure remains unchanged both in the tertiary topology and quaternary structure. These results sharply contrast with the conclusions of Crane *et al.*, (1998) who proposed that large conformational changes concomitant with  $\text{BH}_4$  binding were necessary for inducible NOS dimerization. By comparison of the pterin-bound and pterin-free structures, it is clear that the site preexists (FIG. 3) and does not form via an induced fit process. The pterin-free structure also does not show any major changes at the active site either in the substrate- or inhibitor (*S*-ethylisothiouraea, SEITU)-bound conformations.

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Third, in addition to the new  $\text{ZnS}_4$  center, the most striking and novel finding is the identification of an L-Arg bound to the pterin site in the absence of  $\text{BH}_4$  (FIG. 3A and FIG. 3D). The mode of L-Arg interaction at the pterin site surprisingly mimics that entertained by  $\text{BH}_4$  itself. Two crucial H-bonds, one between a guanidino N with the heme propionate and the other between the primary amino group and Ser 104 are strictly conserved (FIG. 3D). Moreover, the planar guanidinium group is sandwiched between two aromatic groups, one from each monomer, exactly as in the  $\text{BH}_4$  complex. Solvent interactions also are similar to the  $\text{BH}_4$  complex. The affinity for L-Arg must be great since no exogenous L-Arg was added during crystallization. The specificity of L-Arg recognition at the pterin site appears to require both the guanidino function and the primary amino group since SEITU was unable to displace L-Arg from the pterin site.

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The inventors' observation involving L-Arg mimicry of BH<sub>4</sub> has not been previously observed and has broad evolutionary implications. It is possible that the pterin site was originally an L-Arg binding site and later evolved into a BH<sub>4</sub> site. The "arginine paradox" (McDonald *et al.*, 1997), which refers to the ability of extracellular L-Arg to drive NO<sup>•</sup> biosynthesis, amidst the large intracellular substrate pool, suggests limited substrate availability in specialized cellular compartments and may have favored the evolution of a second L-Arg site as a substrate reserve in a primordial setting. The inventors propose that the higher affinity of NOS for BH<sub>4</sub> (K<sub>d</sub> ~ 20 nM; Werner-Felmayer and Gross, 1996) evolved to repel competition from L-Arg which is abundant in cells (0.2 - 0.8 mM; Hecker *et al.*, 1990). A striking corollary can be established between the inventors' finding and the ability of *Tetrahymena* group I catalytic RNA to specifically recognize L-Arg as a mimic for guanosine binding (Yarus, 1988).

Given this elegant mimicry of the obligatory cofactor by L-Arg, the question arises as to why NOS chose a pterin in place of L-Arg for sustaining function. The strict requirement for reduced pterin cannot apparently be explained by a purely structural role since L-Arg can serve this same function. BH<sub>4</sub> likely plays a direct functional role. A well-known function of pterin is to cycle between quinonoid BH<sub>2</sub> and BH<sub>4</sub> in metal-dependent aromatic amino acid hydroxylases (Kaufman, 1997). To date, direct evidence for both pterin cycling and pterin function in NOS is lacking (Hemmings and Mayer, 1997). The inventors' finding that the pterin site in NOS recruits L-Arg, provides structural insights on why BH<sub>4</sub> can serve as a single electron donor. The guanidino group of L-Arg is one of the strongest organic bases and the ability of the pterin site to bind L-Arg argues in favor of preferential binding of a fully protonated species of BH<sub>4</sub>. Owing to the essentially identical nature of the pterin site in both the L-Arg and BH<sub>4</sub> complexes, it appears that bound BH<sub>4</sub> experiences the same electrostatic environment as L-Arg.

The inventors propose a mechanism (FIG. 5) in which the NOS pterin site modulates the pK<sub>a</sub> of N5 of the pyrazine ring and also provides an "acidic" milieu known to stabilize pterin radicals (Pfleiderer, 1985; Kappock and Caradonna, 1996; Eberlein *et*

*al.*, 1984) that can serve as one electron donors (Bec *et al.*, 1998) in NO<sup>•</sup> biosynthesis. Cycling from the pterin radical back to BH<sub>4</sub> may be achieved *via* electron transfer from the reductase domain while the pterin remains bound to NOS. Another important structural feature that will substantially contribute to pterin radical stabilization is the  $\pi$  stacking interaction with Trp 449. Such aromatic stacking is not found in binding sites of other pterin utilizing enzymes (Bourne *et al.*, 1991; Auerbach *et al.*, 1997), but resonance stabilization of flavin semiquinone radical found in flavoproteins are mediated through stacking interactions (Massey, 1994; Wang *et al.*, 1997). NOS provides an interesting scenario in which an enzyme has evolved to produce a pterin function that may mimic flavoprotein systems in structure and function.

Finally, the pterin-free eNOS structure also has relevance to human medicine. There is strong evidence for superoxide generation by the heme domain of eNOS in the absence of BH<sub>4</sub> thereby leading to potential pathophysiology. Endothelial dysfunction is reversed in hypercholesterolemic patients treated with BH<sub>4</sub> and has been shown to be a NOS related action (Stroes *et al.*, 1997; Piper, 1997; Kinoshita *et al.*, 1997; Cosentino *et al.*, 1998). It is conceivable that BH<sub>4</sub> deficient eNOS may be a reality in vascular pathologies in which L-Arg could substitute at the BH<sub>4</sub> site in pterin-depleted states. The availability of pterin-free eNOS structure paves the way for rational design of both pterin-dependent and independent activators that can restore endothelial function. These and other implications of the findings present herein are discussed in further detail herein below.

## **B. Crystallization Techniques**

The techniques used for the crystallization of a protein for crystallographic resolution of protein are well known to those of skill in the art. One technique for crystallization is referred to as the microbatch technique. The microbatch technique is ideal for the rapid determination of the phase diagram of a protein. If the concentration of crystallizable protein is plotted against the concentration of a precipitant, microbatch results can be used to divide the space represented into several areas. Microbatching has

been extensively described in the literature, see for example, Chayen *et al.*, 1990; Chayen *et al.*, 1992; Chayen *et al.*, 1994.

In microbatching, at high concentrations of both protein and precipitant, the protein precipitates as an amorphous material. At lower concentrations, crystal nuclei may form, which may grow to form diffracting crystals. At still lower concentrations, nuclei will not form, so generally no crystals appear. However, if a nucleus or crystal is placed in such a solution, it will grow to form a large crystal. This area, where crystal growth but not nucleation takes place, is sometimes referred to as "the metastable zone". At the lowest concentrations, the protein is completely soluble. It is often found that crystals grown in the metastable zone are better ordered and diffract better than crystals grown at higher concentrations. The microseeding approach described herein below includes a simple method of finding the metastable zone and introducing crystal seeds to it.

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Single crystals of a given protein are generally obtained by microseeding, a valuable measurement in this step is the precipitation point of a protein at a single protein concentration which is described by Stewart and Khimasia (1994). A well with a well-formed crystal is selected and the crystal is transferred to a glass depression plate containing 40  $\mu$ l of harvesting buffer with a high PEG concentration. The initial crystal is ground up with a needle or a glass fibre with a ball at the tip. The resulting suspension is added to an Eppendorf tube containing 100  $\mu$ l of the harvesting buffer the tube was centrifuged for a five minutes at around 100 g. The supernatant from this step contains the seeds; this supernatant may then be diluted to yield varying concentrations of seeding solution. The seeding solutions are used to seed sitting drop crystallization trials in appropriate crystallization plates (e.g., CrystalClear plates Douglas Instruments). 100  $\mu$ l of solution was used in the reservoirs. Next, buffer, protein and PEG are dispensed automatically into the sample wells of the CrystalClear plates. By dispensing droplets marginally below the reservoir concentration, the need for equilibration before seeding may be avoided - the concentration was not so low that the nuclei dissolved. Finally 0.3  $\mu$ l of each of the seeding solutions produced is added by hand to each sample well with a

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5  $\mu$ l Hamilton syringe. The plates were then sealed and crystals allowed to form. Small single crystals will appear after several days.

Large crystals are obtained by macroseeding. Using a rayon loop, a small single crystal is transferred into reservoir solution, allowed to wash for several minutes, and then transferred into another drop that has been equilibrated for 3-5 days. The same reservoir and drop condition used to obtain the initial aggregates also are used for the subsequent micro and macroseeding. The crystals attain their maximum size in 5-10 days following macroseeding. Typical crystal dimensions are 0.3 mm  $\times$  0.3 mm  $\times$  0.6 mm.

10

### C. Specific eNOS Active Site Modifications

Given that the present invention has determined the crystal structure of eNOS, it is now possible to modify various specific residues within the protein to determine the roles of particular residues within the active site. The following is a discussion based upon changing the amino acids of a protein to create an equivalent, or even an improved, second-generation molecule. The amino acid changes may be achieved by changing the codons of the DNA sequence, according to the following codon table, Table 1:

15

TABLE 1

Amino Acid Names and abbreviations			Codons							
Alanine	Ala	A	GCA	GCC	GCG	GCU				
Cysteine	Cys	C	UGC	UGU						
Aspartic acid	Asp	D	GAC	GAU						
Glutamic acid	Glu	E	GAA	GAG						
Phenylalanine	Phe	F	UUC	UUU						
Glycine	Gly	G	GGA	GGC	GGG	GGU				
Histidine	His	H	CAC	CAU						
Isoleucine	Ile	I	AUA	AUC	AUU					
Lysine	Lys	K	AAA	AAG						
Leucine	Leu	L	UUA	UUG	CUA	CUC	CUG	CUU		
Methionine	Met	M	AUG							
Asparagine	Asn	N	AAC	AAU						
Proline	Pro	P	CCA	CCC	CCG	CCU				
Glutamine	Gln	Q	CAA	CAG						
Arginine	Arg	R	AGA	AGG	CGA	CGC	CGG	CGU		
Serine	Ser	S	AGC	AGU	UCA	UCC	UCG	UCU		
Threonine	Thr	T	ACA	ACC	ACG	ACU				
Valine	Val	V	GUA	GUC	GUG	GUU				
Tryptophan	Trp	W	UGG							
Tyrosine	Tyr	Y	UAC	UAU						

It is known that certain amino acids may be substituted for other amino acids in a protein structure in order to modify or improve its antigenicity or activity (see, *e.g.*, Kyte and Doolittle, 1982; Hopp, U.S. Patent 4,554,101, incorporated herein by reference). For example, through the substitution of alternative amino acids, small conformational changes may be conferred upon a polypeptide which result in increased activity or stability. Alternatively, amino acid substitutions in certain polypeptides may be utilized to provide residues which may then be linked to other molecules to provide peptide-molecule conjugates which retain enough antigenicity of the starting peptide to be useful for other purposes. For example, a selected eNOS peptide bound to a solid support might be constructed which would have particular advantages in diagnostic embodiments.

The importance of the hydropathic index of amino acids in conferring interactive biological function on a protein has been discussed generally by Kyte and Doolittle (1982), wherein it is found that certain amino acids may be substituted for other amino acids having a similar hydropathic index or core and still retain a similar biological activity. As displayed in Table 2 below, amino acids are assigned a hydropathic index on the basis of their hydrophobicity and charge characteristics. It is believed that the relative hydropathic character of the amino acid determines the secondary structure of the resultant protein, which in turn defines the interaction of the protein with substrate molecules. Preferred substitutions which result in an antigenically equivalent peptide or protein will generally involve amino acids having index scores within  $\pm 2$  units of one another, and more preferably within  $\pm 1$  unit, and even more preferably, within  $\pm 0.5$  units.

TABLE 2

Amino Acid	Hydropathic Index
Isoleucine	4.5
Valine	4.2
Leucine	3.8
Phenylalanine	2.8
Cysteine/cystine	2.5
Methionine	1.9
Alanine	1.8
Glycine	-0.4
Threonine	-0.7
Tryptophan	-0.9
Serine	-0.8
Tyrosine	-1.3
Proline	-1.6
Histidine	-3.2
Glutamic Acid	-3.5
Glutamine	-3.5
Aspartic Acid	-3.5
Asparagine	-3.5
Lysine	-3.9
Arginine	-4.5

Thus, for example, isoleucine, which has a hydropathic index of +4.5, will preferably be exchanged with an amino acid such as valine (+ 4.2) or leucine (+ 3.8). Alternatively, at the other end of the scale, lysine (- 3.9) will preferably be substituted for arginine (-4.5), and so on.

Substitution of like amino acids may also be made on the basis of hydrophilicity, particularly where the biological functional equivalent protein or peptide thereby created is intended for use in immunological embodiments. U.S. Patent 4,554,101, incorporated herein by reference, states that the greatest local average hydrophilicity of a protein, as governed by the hydrophilicity of its adjacent amino acids, correlates with its

immunogenicity and antigenicity, *i.e.* with an important biological property of the protein.

As detailed in U.S. Patent 4,554,101, each amino acid has also been assigned a hydrophilicity value. These values are detailed below in Table 3.

TABLE 3

Amino Acid	Hydrophilic Index
arginine	+3.0
lysine	+3.0
aspartate	+3.0 $\pm$ 1
glutamate	+3.0 $\pm$ 1
serine	+0.3
asparagine	+0.2
glutamine	+0.2
glycine	0
threonine	-0.4
alanine	-0.5
histidine	-0.5
proline	-0.5 $\pm$ 1
cysteine	-1.0
methionine	-1.3
valine	-1.5
leucine	-1.8
isoleucine	-1.8
tyrosine	-2.3
phenylalanine	-2.5
tryptophan	-3.4

It is understood that one amino acid can be substituted for another having a similar hydrophilicity value and still obtain a biologically equivalent, and in particular, an immunologically equivalent protein. In such changes, the substitution of amino acids whose hydrophilicity values are within  $\pm 2$  is preferred, those which are within  $\pm 1$  are particularly preferred, and those within  $\pm 0.5$  are even more particularly preferred.

Accordingly, these amino acid substitutions are generally based on the relative similarity of R-group substituents, for example, in terms of size, electrophilic character, charge, and the like. In general, preferred substitutions which take various of the foregoing characteristics into consideration will be known to those of skill in the art and include, for example, the following combinations: arginine and lysine; glutamate and aspartate; serine and threonine; glutamine and asparagine; and valine, leucine and isoleucine.

As outlined above, amino acid substitutions are generally therefore based on the relative similarity of the amino acid side-chain substituents, for example, their hydrophobicity, hydrophilicity, charge, size, and the like. Exemplary substitutions which take various of the foregoing characteristics into consideration are well known to those of skill in the art and include: arginine and lysine; glutamate and aspartate; serine and threonine; glutamine and asparagine; and valine, leucine and isoleucine (See Table 4, below). The present invention thus contemplates functional or biological equivalents of an eNOS or variant eNOS polypeptide as set forth above.

TABLE 4

Original Residue	Exemplary Substitutions
Ala	Gly; Ser
Arg	Lys
Asn	Gln; His
Asp	Glu
Cys	Ser
Gln	Asn
Glu	Asp
Gly	Ala
His	Asn; Gln
Ile	Leu; Val
Leu	Ile; Val
Lys	Arg
Met	Met; Leu; Tyr
Ser	Thr
Thr	Ser
Trp	Tyr
Tyr	Trp; Phe
Val	Ile; Leu

Biological or functional equivalents of a polypeptide can also be prepared using  
5 site-specific mutagenesis. Site-specific mutagenesis is a technique useful in the  
preparation of second generation polypeptides, or biologically functional equivalent  
polypeptides or peptides, derived from the sequences thereof, through specific  
mutagenesis of the underlying DNA. As noted above, such changes can be desirable  
where amino acid substitutions are desirable. The technique further provides a ready  
10 ability to prepare and test sequence variants, for example, incorporating one or more of  
the foregoing considerations, by introducing one or more nucleotide sequence changes  
into the DNA. Site-specific mutagenesis allows the production of mutants through the  
use of specific oligonucleotide sequences which encode the DNA sequence of the desired  
mutation, as well as a sufficient number of adjacent nucleotides, to provide a primer  
15 sequence of sufficient size and sequence complexity to form a stable duplex on both sides

of the deletion junction being traversed. Typically, a primer of about 17 to 25 nucleotides in length is preferred, with about 5 to 10 residues on both sides of the junction of the sequence being altered.

5 In general, the technique of site-specific mutagenesis is well known in the art, as exemplified by Adelman, *et al.* (1983). As will be appreciated, the technique typically employs a phage vector which can exist in both a single stranded and double stranded form. Typical vectors useful in site-directed mutagenesis include vectors such as the M13 phage (Messing, *et al.*, 1981). These phage are commercially available and their  
10 use is generally known to those of skill in the art.

In general, site-directed mutagenesis in accordance herewith is performed by first obtaining a single-stranded vector which includes within its sequence a DNA sequence which encodes all or a portion of the eNOS or variant eNOS enzyme polypeptide  
15 sequence selected. An oligonucleotide primer bearing the desired mutated sequence is prepared, generally synthetically, for example, by the method of Crea *et al.*, (1978). This primer is then annealed to the singled-stranded vector, and extended by the use of enzymes such as *E. coli* polymerase I Klenow fragment, in order to complete the synthesis of the mutation-bearing strand. Thus, a heteroduplex is formed wherein one  
20 strand encodes the original non-mutated sequence and the second strand bears the desired mutation. This heteroduplex vector is then used to transform appropriate cells such as *E. coli* cells and clones are selected which include recombinant vectors bearing the mutation. Commercially available kits come with all the reagents necessary, except the oligonucleotide primers.

25 In addition, peptides derived from these polypeptides, including peptides of at least about 6 consecutive amino acids from these sequences, are contemplated. Alternatively, such peptides may comprise about 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41,  
30 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59 or 60 consecutive residues. For example, a peptide that comprises 6 consecutive amino acid residues may



comprise residues 1 to 6, 2 to 7, 3 to 8 and so on of the eNOS protein. Such peptides may be represented by the formula

$x$  to  $(x + n) = 5'$  to  $3'$  the positions of the first and last consecutive residues

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where  $x$  is equal to any number from 1 to the full length of the eNOS protein and  $n$  is equal to the length of the peptide minus 1. Where the peptide is 10 residues long ( $n = 10 - 1$ ), the formula represents every 10-mer possible for each antigen. For example, where  $x$  is equal to 1 the peptide would comprise residues 1 to  $(1 + [10 - 1])$ , or 1 to 10. Where  $x$  is equal to 2, the peptide would comprise residues 2 to  $(2 + [10 - 2])$ , or 2 to 11, and so on.

10

Syntheses of peptides are readily achieved using conventional synthetic techniques such as the solid phase method (*e.g.*, through the use of a commercially available peptide synthesizer such as an Applied Biosystems Model 430A Peptide Synthesizer). Peptides synthesized in this manner may then be aliquoted in predetermined amounts and stored in conventional manners, such as in aqueous solutions or, even more preferably, in a powder or lyophilized state pending use.

15

In general, due to the relative stability of peptides, they may be readily stored in aqueous solutions for fairly long periods of time if desired, *e.g.*, up to six months or more, in virtually any aqueous solution without appreciable degradation or loss of antigenic activity. However, where extended aqueous storage is contemplated it will generally be desirable to include agents including buffers such as Tris or phosphate buffers to maintain a pH of 7.0 to 7.5. Moreover, it may be desirable to include agents which will inhibit microbial growth, such as sodium azide or Merthiolate. For extended storage in an aqueous state it will be desirable to store the solutions at 4°C, or more preferably, frozen. Of course, where the peptide(s) are stored in a lyophilized or powdered state, they may be stored virtually indefinitely, *e.g.*, in metered aliquots that may be rehydrated with a predetermined amount of water (preferably distilled, deionized) or buffer prior to use.

25

30

Of particular interest are peptides that represent antigenic epitopes that lie within the eNOS polypeptides of the present invention. An "epitope" is a region of a molecule that stimulates a response from a T-cell or B-cell, and hence, elicits an immune response from these cells. An epitopic core sequence, as used herein, is a relatively short stretch of amino acids that is structurally "complementary" to, and therefore will bind to, binding sites on antibodies or T-cell receptors. It will be understood that, in the context of the present disclosure, the term "complementary" refers to amino acids or peptides that exhibit an attractive force towards each other. Thus, certain epitopic core sequences of the present invention may be operationally defined in terms of their ability to compete with or perhaps displace the binding of the corresponding eNOS antigen to the corresponding eNOS-directed antisera.

The identification of epitopic core sequences is known to those of skill in the art. For example U.S. Patent 4,554,101 teaches identification and preparation of epitopes from amino acid sequences on the basis of hydrophilicity, and by Chou-Fasman analyses. Numerous computer programs are available for use in predicting antigenic portions of proteins, examples of which include those programs based upon Jameson-Wolf analyses (Jameson and Wolf, 1988; Wolf *et al.*, 1988), the program PepPlot® (Brutlag *et al.*, 1990; Weinberger *et al.*, 1985), and other new programs for protein tertiary structure prediction (Fetrow and Bryant, 1993) that can be used in conjunction with computerized peptide sequence analysis programs.

In general, the size of the polypeptide antigen is not believed to be particularly crucial, so long as it is at least large enough to carry the identified core sequence or sequences. The smallest useful core sequence anticipated by the present disclosure would be on the order of about 6 amino acids in length. Thus, this size will generally correspond to the smallest peptide antigens prepared in accordance with the invention. However, the size of the antigen may be larger where desired, so long as it contains a basic epitopic core sequence.

**D. Small Molecule Modulators of eNOS**

The present invention provides methods for screening and identifying small molecule modulators of eNOS proteins and identifies such compounds. One rationale behind the design of the small molecule eNOS protein modulators is that in the absence of BH<sub>4</sub> it is seen that the heme domain of eNOS generates superoxide radicals thereby leading to pathophysiology. For example, further endothelial dysfunction in hypercholesterolemia is reversed as a result of BH<sub>4</sub> treatment. The activated eNOS protein is thus able to produce NO and restore endothelial function. The present invention provides a pterin-free eNOS structure that can be used to model drugs (i.e., ligands) that will ameliorate the effect of BH<sub>4</sub> depletion. Such ligands will be useful in any diseased state in which NO signaling is defective or insufficient.

The findings of the present invention will be exploited to design chemical ligands that bind to the active site of the different variant proteins to yield complexes with sufficient thermodynamic stability to effectively modulate the functional activity of the protein. To obtain appropriate ligands that bind to the active sites of different eNOS variant proteins, the inventors may utilize the technique of force-field docking of chemical fragments from both commercially available chemical fragment libraries, as well as in-house generated libraries, into the active electrophile-binding (H-) site in the derived crystal structure of each variant protein. The docked fragments will be energy-minimized and the binding energies computed and used to select candidate ligands.

*Generation of eNOS modulators:* Generation of modulators is accomplished by a rational drug development strategy involving force field docking and energy-minimization of chemical fragments and compounds into the active site of the eNOS protein(s). The. Additional chemical libraries also may be generated as necessary. The active compounds and chemical fragments can be drawn from chemical fragment libraries, such as that available in the Leapfrog database site and other structural components of the eNOS proteins will be derived from the crystal structure of the eNOS described by the present invention.

One potential substitution that confers a functional change to the eNOS protein is to replace Cys 101 and/or Ser 104 which bond to BH<sub>4</sub> (FIG. 4). In addition, Val 105, which forms a direct nonbonded contact with BH<sub>4</sub> may be altered. Therefore, disruption of the metal center either by demetallation or ligand removal via mutagenesis will distort this region of the polypeptide chain resulting in greatly diminished affinity for BH<sub>4</sub>. Additional mutations are contemplated which may result in increased stability. For example, increased protein stability results from the addition of disulfide bonds and the creation of more hydrophobic interactions within the protein structure.

Based on the resultant DDH values obtained after energy minimization of chemical fragments/compounds, candidate modulators are selected and/or newly constructed from chemical fragments for synthesis and further analyses for their inhibitory or other action on the eNOS proteins. Selection criteria for such modulators for synthesis and further analysis includes lipophilicity, chemical stability, and availability or ease of synthesis.

If the identified and/or newly constructed potential inhibitors are not commercially available, then they will be synthesized using standard organic synthetic methodology, including heterocyclic ring construction and functionalization, and electrophilic and nucleophilic substitution reactions. Reaction mixtures will be separated by thin layer, flash silica gel column, and high performance liquid chromatography (TLC, CC and HPLC). The compounds will be purified using standard techniques modified as necessary. Characterization of synthetic products will be done by melting point determination, Fourier transform infrared (FT-IR), ultraviolet (UV), and high resolution nuclear magnetic resonance (NMR) spectroscopy and mass spectrometry. Compounds for biological testing will be purified by preparative HPLC. The purity of compounds will be determined by elemental analysis and HPLC.

Candidate modulators of the present invention will be useful in the treatment of nitric oxide synthase mediated diseases and disorders, including neurodegenerative disorders, disorders of gastrointestinal motility and inflammation. These disease and

disorders include hypotension, septic shock, toxic shock syndrome, hemodialysis, IL-2 therapy such as in cancer patients, cachexia, immunosuppression such as in transplant therapy, autoimmune and/or inflammatory indications including sunburn or psoriasis and respiratory conditions such as bronchitis, asthma, and acute respiratory distress (ARDS), myocarditis, heart failure, atherosclerosis, arthritis, rheumatoid arthritis, chronic or inflammatory bowel disease, ulcerative colitis, Crohn's disease, systemic lupus erythematosus (SLE), ocular conditions such as ocular hypertension and uveitis, type 1 diabetes, insulin-dependent diabetes mellitus, and cystic fibrosis. These compounds will be similar to those already described in the art in for example, U.S. Patent 5,821,261; U.S. Patent 5,821,267; U.S. Patent 5,807,886; U.S. Patent 5,776,979; U.S. Patent 5,767,160; U.S. Patent 5,728,728; U.S. Patent 5,723,451; U.S. Patent 5,710,181; U.S. Patent 5,688,499; U.S. Patent 5,684,008; U.S. Patent 5,674,907; U.S. Patent 5,645,839; U.S. Patent 5,629,322; U.S. Patent 5,585,402; U.S. Patent 5,543,430; U.S. Patent 5,480,999; U.S. Patent 5,436,271; U.S. Patent 5,380,945; U.S. Patent 5,362,747; U.S. Patent 5,296,466 and U.S. Patent 5,266,594 (each incorporated herein by reference). The compositions disclosed in these patents may be used as starting materials for rational drug design to yield modulators that best fit the crystal structure of NOS described herein.

The different compounds may have varying substituents which result in significant changes in binding energies of the compounds in the active site pocket of the eNOS protein. An individual skilled in the art of organic synthesis in light of the present disclosure will be able to prepare or identify a large variety of candidate molecules which would be expected to have eNOS modulatory effects in the light of the present disclosure.

25

The modulators identified may be inhibitors or stimulators of eNOS activity. Inhibitors will be used in treating various conditions where there is an advantage in inhibiting nitric oxide biosynthesis, as described in e.g., U.S. Patent 5,821,261; U.S. Patent 5,821,267; U.S. Patent 5,807,886; U.S. Patent 5,789,442; U.S. Patent 5,789,395; U.S. Patent 5,776,979; U.S. Patent 5,756,540; U.S. Patent 5,741,815; U.S. Patent 5,723,451; U.S. Patent 5,721,278; U.S. Patent 5,710; U.S. Patent 5,710,181; U.S. Patent 5,695,761; U.S. Patent

5,684,008; U.S. Patent 5,674,907; 5,645,839; U.S. Patent 5,629,322; U.S. Patent 5,585,402. Inhibition of NOS activity will be useful in treating conditions such as hypotension, inhibition of ovulation, inflammatory bowel disease, inflammation, autoimmune diseases and septic shock variety of cardiovascular fibrotic pathologies, such as that associated with left ventricular hypertrophy secondary to hypertension, myocardial infarction, myocarditis, and the like. Stimulators will be useful in treating conditions where there is an advantage to stimulating nitric oxide biosynthesis. Such conditions include diseases related to vasoconstriction, wherein the vasoconstriction is relieved by stimulating the NOS to produce native nitric oxide, e.g., as described in U.S. Patent 5,767,160; 5,543,430; stimulation of ovulation as described in U.S. Patent 5,721,278. NOS stimulators also are used to slow and reverse the process of fibrosis in the body, useful in the treatment of a variety of cardiovascular fibrotic pathologies, such as that associated with left ventricular hypertrophy secondary to hypertension, myocardial infarction, and myocarditis as described in U.S. Patent 5,645,839.

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*Screening for modulators of eNOS:* Within certain embodiments of the invention, methods are provided for screening for modulators of eNOS protein activity. Such methods may use labeled eNOS proteins or analogs, anti-eNOS proteins or anti-eNOS antibodies and the like as reagents to screen small molecule and peptide libraries to identify modulators of eNOS protein activity. Within one example, a modulator screening assay is performed in which cells expressing eNOS proteins are exposed to a test substance under suitable conditions and for a time sufficient to permit the agent to effect activity of eNOS proteins.

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Generally the test substance is added in the form of a purified agent. However, it is also contemplated that test substances useful within the invention may include substances present throughout the handling of test sample components. For example, host cell factors that are present in a cell lysate may be used for generating the test sample. Such endogenous factors may be segregated between the test and control samples, for example, by using different cell types for preparing lysates. In such

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preparations, the cell type used for preparing the test sample expresses a putative test substance that is not expressed by the cell type used in preparing the control sample.

5 The active compounds may include fragments or parts of naturally-occurring compounds or may be only found as active combinations of known compounds which are otherwise inactive. However, prior to testing of such compounds in humans or animal models, it may be necessary to test a variety of candidates to determine which have potential.

10 Accordingly, in screening assays to identify agents which alter the activity of eNOS proteins, it is proposed that compounds isolated from natural sources, such as animals, bacteria, fungi, plant sources, including leaves and bark, and marine samples may be assayed as candidates for the presence of potentially useful pharmaceutical agents. It will be understood that the pharmaceutical agents to be screened could also be  
15 derived or synthesized from chemical compositions or man-made compounds.

In these embodiments, the present invention is directed to a method for determining the ability of a candidate substance to decrease the eNOS activity of cells, the method including generally the steps of:

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- (a) obtaining a cell with eNOS activity;
- (b) admixing a candidate substance with the cell; and
- (c) determining the ability of the candidate substance to inhibit the eNOS activity of the cell.

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To identify a candidate substance as being capable of decreasing eNOS activity, one would measure or determine the basal eNOS status of the cell prior to any additions or manipulation. One would then add the candidate substance to the cell and re-determine the eNOS activity in the presence of the candidate substance. A candidate  
30 substance which decreases the eNOS activity relative to the composition in its absence is

indicative of a candidate substance being an inhibitor of eNOS. A similar assay may be set up to determine whether the candidate substance is a stimulator of eNOS activity.

"Effective amounts", in certain circumstances, are those amounts effective to reproducibly alter eNOS activity in an assay in comparison to their normal levels. Compounds that achieve significant appropriate changes in activity will be used. If desired, a battery of compounds may be screened *in vitro* to identify other agents for use in the present invention.

A significant change in eNOS activity is represented by a change in eNOS protein activity levels of at least about 30%-40%, and most preferably, by a change of at least about 50%, with higher values of course being possible. Assays that measure eNOS activity in cells are well known in the art and may be conducted *in vitro* or *in vivo*, and have been described elsewhere in the specification.

Quantitative *in vitro* testing of the eNOS modulators is not a requirement of the invention as it is generally envisioned that the agents will often be selected on the basis of their known properties or by structural and/or functional comparison to those agents already demonstrated to be effective. Therefore, the effective amounts often will be those amounts proposed to be safe for administration to animals in another context.

#### **E. Antibodies to eNOS**

Within certain embodiments of the present invention, antibodies raised against eNOS may be useful in aiding the identification of drugs. An antibody that recognizes the active site of an enzyme will act as a mimic of the drug that fits that active site. Using this information, drugs may be designed that mimic the shape of such an antibody.

Antibodies to eNOS variant peptides or polypeptides may be readily prepared through use of well-known techniques, such as those exemplified in U.S. Patent 4,196,265. Typically, this technique involves immunizing a suitable animal with a selected immunogen composition, *e.g.*, purified or partially purified protein, synthetic



protein or fragments thereof, as discussed in the section on polypeptides. Animals to be immunized are mammals such as cats, dogs, and horses, although there is no limitation other than that the subject be capable of mounting an immune response of some kind. The immunizing composition is administered in a manner effective to stimulate antibody producing cells. Rodents such as mice and rats are preferred animals. However, the use of rabbits, sheep or frogs is possible. The use of rats may provide certain advantages, but mice are preferred, with the BALB/c mouse being most preferred as the most routinely used animal and one that generally gives a higher percentage of stable fusions.

For generation of monoclonal antibodies (MAbs), following immunization, somatic cells with the potential for producing antibodies, specifically B lymphocytes (B cells), are selected for use in the MAb generating protocol. These cells may be obtained from biopsied spleens, tonsils or lymph nodes, or from a peripheral blood sample. Spleen cells and peripheral blood cells are preferred, the former because they are a rich source of antibody-producing cells that are in the dividing plasmablast stage, and the latter because peripheral blood is easily accessible. Often, a panel of animals will have been immunized and the spleen of the animal with the highest antibody titer removed. Spleen lymphocytes are obtained by homogenizing the spleen with a syringe. Typically, a spleen from an immunized mouse contains approximately  $5 \times 10^7$  to  $2 \times 10^8$  lymphocytes.

The antibody-producing B cells from the immunized animal are then fused with cells of an immortal myeloma cell line, generally one of the same species as the animal that was immunized. Myeloma cell lines suited for use in hybridoma-producing fusion procedures preferably are non-antibody-producing, have high fusion efficiency and enzyme deficiencies that render them incapable of growing in certain selective media which support the growth of only the desired fused cells, called "hybridomas."

Any one of a number of myeloma cells may be used and these are known to those of skill in the art. For example, where the immunized animal is a mouse, one may use P3-X63/Ag8, X63-Ag8.653, NS1/1.Ag 41, Sp210-Ag14, FO, NSO/U, MPC-11,

MPC11-X45-GTG 1.7 and S194/5XX0 Bul; for rats, one may use R210.RCY3, Y3-Ag 1.2.3, IR983F and 4B210; and U-266, GM1500-GRG2, LICR-LON-HMy2 and UC729-6 are all useful in connection with human cell fusions.

5           One preferred murine myeloma cell line is the NS-1 myeloma cell line (also termed P3-NS-1-Ag4-1), which is readily available from the NIGMS Human Genetic Mutant Cell Repository by requesting cell line repository number GM3573. Another mouse myeloma cell line that may be used is the 8-azaguanine-resistant mouse murine myeloma SP2/0 non-producer cell line.

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          Methods for generating hybrids of antibody-producing spleen or lymph node cells and myeloma cells usually comprise mixing somatic cells with myeloma cells in a 2:1 proportion, though the proportion may vary from about 20:1 to about 1:1, respectively, in the presence of an agent or agents (chemical or electrical) that promote the fusion of cell  
15   membranes. Fusion methods using Sendai virus have been described by Kohler & Milstein (1975; 1976), and those using polyethylene glycol (PEG), such as 37% (v/v) PEG, by Gefter *et al.* (1977). The use of electrically induced fusion methods is also appropriate.

20           Fusion procedures usually produce viable hybrids at low frequencies, from about  $1 \times 10^{-6}$  to  $1 \times 10^{-8}$ . This does not pose a problem, however, as the viable, fused hybrids are differentiated from the parental, unfused cells (particularly the unfused myeloma cells that would normally continue to divide indefinitely) by culture in a selective medium. The selective medium generally is one that contains an agent that blocks the *de novo*  
25   synthesis of nucleotides in the tissue culture media. Exemplary and preferred agents are aminopterin, methotrexate, and azaserine. Aminopterin and methotrexate block *de novo* synthesis of both purines and pyrimidines, whereas azaserine blocks only purine synthesis. Where aminopterin or methotrexate is used, the media is supplemented with hypoxanthine and thymidine as a source of nucleotides (HAT medium). Where azaserine  
30   is used, the media is supplemented with hypoxanthine.

The preferred selection medium is HAT. Only cells capable of operating nucleotide salvage pathways are able to survive in HAT medium. The myeloma cells are defective in key enzymes of the salvage pathway, *e.g.*, hypoxanthine phosphoribosyl transferase (HPRT), and they cannot survive. The B cells can operate this pathway, but they have a limited life span in culture and generally die within about two weeks. Therefore, the only cells that can survive in the selective media are those hybrids formed from myeloma and B cells.

This culturing provides a population of hybridomas from which specific hybridomas are selected. Typically, selection of hybridomas is performed by single-clone dilution in microtiter plates, followed by testing the individual clonal supernatants (after about two to three weeks) for the desired reactivity. The assay should be sensitive, simple, and rapid, such as radioimmunoassays, enzyme immunoassays, cytotoxicity assays, plaque assays, dot immunobinding assays, and the like.

The selected hybridomas are then serially diluted and cloned into individual antibody-producing cell lines, which clones can then be propagated indefinitely to provide MAbs. The cell lines may be exploited for MAb production in two basic ways. A sample of the hybridoma can be injected, usually in the peritoneal cavity, into a histocompatible animal of the type that was used to provide the somatic and myeloma cells for the original fusion. The injected animal develops tumors secreting the specific monoclonal antibody produced by the fused cell hybrid. The body fluids of the animal, such as serum or ascites fluid, can then be tapped to provide MAbs in high concentration. The individual cell lines could also be cultured *in vitro*, where the MAbs are naturally secreted into the culture medium from which they can be readily obtained in high concentrations. MAbs produced by either means may be further purified, if desired, using filtration, centrifugation, and various chromatographic methods such as HPLC or affinity chromatography.

Monoclonal antibodies of the present invention also include anti-idiotypic antibodies produced by methods well-known in the art. Monoclonal antibodies according

to the present invention also may be monoclonal heteroconjugates, *i.e.*, hybrids of two or more antibody molecules. In another embodiment, monoclonal antibodies according to the invention are chimeric monoclonal antibodies. In one approach, the chimeric monoclonal antibody is engineered by cloning recombinant DNA containing the promoter, leader, and variable-region sequences from a mouse antibody producing cell and the constant-region exons from a human antibody gene. The antibody encoded by such a recombinant gene is a mouse-human chimera. Its antibody specificity is determined by the variable region derived from mouse sequences. Its isotype, which is determined by the constant region, is derived from human DNA.

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In another embodiment, monoclonal antibodies according to the present invention is a "humanized" monoclonal antibody, produced by techniques well-known in the art. That is, mouse complementary determining regions ("CDRs") are transferred from heavy and light V-chains of the mouse Ig into a human V-domain, followed by the replacement of some human residues in the framework regions of their murine counterparts. "Humanized" monoclonal antibodies in accordance with this invention are especially suitable for use in *in vivo* diagnostic and therapeutic methods.

As stated above, the monoclonal antibodies and fragments thereof according to this invention can be multiplied according to *in vitro* and *in vivo* methods well-known in the art. Multiplication *in vitro* is carried out in suitable culture media such as Dulbecco's modified Eagle medium or RPMI 1640 medium, optionally replenished by a mammalian serum such as fetal calf serum or trace elements and growth-sustaining supplements, *e.g.*, feeder cells, such as normal mouse peritoneal exudate cells, spleen cells, bone marrow macrophages or the like. *In vitro* production provides relatively pure antibody preparations and allows scale-up to give large amounts of the desired antibodies. Techniques for large scale hybridoma cultivation under tissue culture conditions are known in the art and include homogenous suspension culture, *e.g.*, in an airlift reactor or in a continuous stirrer reactor or immobilized or entrapped cell culture.

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Large amounts of the monoclonal antibody of the present invention also may be obtained by multiplying hybridoma cells *in vivo*. Cell clones are injected into mammals which are histocompatible with the parent cells, *e.g.*, syngeneic mice, to cause growth of antibody-producing tumors. Optionally, the animals are primed with a hydrocarbon, especially oils such as Pristane (tetramethylpentadecane) prior to injection.

In accordance with the present invention, fragments of the monoclonal antibody of the invention can be obtained from monoclonal antibodies produced as described above, by methods which include digestion with enzymes such as pepsin or papain, and/or cleavage of disulfide bonds by chemical reduction. Alternatively, monoclonal antibody fragments encompassed by the present invention can be synthesized using an automated peptide synthesizer, or they may be produced manually using techniques well known in the art.

The monoclonal conjugates of the present invention are prepared by methods known in the art, *e.g.*, by reacting a monoclonal antibody prepared as described above with, for instance, an enzyme in the presence of a coupling agent such as glutaraldehyde or periodate. Conjugates with fluorescein markers are prepared in the presence of these coupling agents, or by reaction with an isothiocyanate. Conjugates with metal chelates are similarly produced. Other moieties to which antibodies may be conjugated include radionuclides such as  $^3\text{H}$ ,  $^{125}\text{I}$ ,  $^{131}\text{I}$ ,  $^{32}\text{P}$ ,  $^{35}\text{S}$ ,  $^{14}\text{C}$ ,  $^{51}\text{Cr}$ ,  $^{36}\text{Cl}$ ,  $^{57}\text{Co}$ ,  $^{58}\text{Co}$ ,  $^{59}\text{Fe}$ ,  $^{75}\text{Se}$ ,  $^{152}\text{Eu}$ , and  $^{99\text{m}}\text{Tc}$ , are other useful labels which can be conjugated to antibodies. Radioactively labeled monoclonal antibodies of the present invention are produced according to well-known methods in the art. For instance, monoclonal antibodies can be iodinated by contact with sodium or potassium iodide and a chemical oxidizing agent such as sodium hypochlorite, or an enzymatic oxidizing agent, such as lactoperoxidase. Monoclonal antibodies according to the invention may be labeled with technetium- $^{99\text{m}}$  by ligand exchange process, for example, by reducing pertechnetate with stannous solution, chelating the reduced technetium onto a Sephadex column and applying the antibody to this column or by direct labeling techniques, *e.g.*, by incubating pertechnetate, a reducing agent

such as  $\text{SNCl}_2$ , a buffer solution such as sodium-potassium phthalate solution, and the antibody.

#### F. Examples

5       The following examples are included to demonstrate preferred embodiments of the invention. It should be appreciated by those of skill in the art that the techniques disclosed in the examples which follow represent techniques discovered by the inventor to function well in the practice of the invention, and thus can be considered to constitute preferred modes for its practice. However, those of skill in the art should, in light of the  
10       present disclosure, appreciate that many changes can be made in the specific embodiments which are disclosed and still obtain a like or similar result without departing from the spirit and scope of the invention.

#### EXAMPLE 1

##### 15       Determination of the Crystal Structure of eNOS

Crystals were grown as described. Briefly, bovine eNOS heme domain (39-482; Mr 49,000) was obtained *via* trypsinolysis of a modified version of the holo eNOS construct (expressed in *E. coli*) missing 75% of the calmodulin binding region. Crystals  
20       suitable for diffraction were grown by the sitting drop vapor-diffusion method from 15% PEG 3350, 200 mM magnesium acetate, 100 mM sodium cacodylate, pH 6.5, and 2 mM *S*-ethylisothiurea (or 10 mM L-Arg) in the presence of 75  $\mu\text{M}$  sodium dodecyl sulfate (SDS) as an additive and 10 mM tris(2-carboxyethyl)phosphine (TCEP) or 5 mM glutathione sulfonate as reducing agent. No  $\text{BH}_4$  was added during crystallization.  
25       Pterin-free protein expressed in *E. coli* was purified either in the presence (50  $\mu\text{M}$ ) or absence of  $\text{BH}_4$  towards obtaining crystals with cofactor-bound and -free forms. Crystals grown under these conditions belong to the orthorhombic space group,  $\text{P}2_12_12_1$ , with cell constants  $a=58.00 \text{ \AA}$ ,  $b=106.55 \text{ \AA}$ , and  $c=156.22 \text{ \AA}$ . There is one dimer in the asymmetric unit (50% solvent content). All native and derivative crystals were flash frozen in liquid  
30       nitrogen for both storage and data collection at cryogenic temperatures (100 K). A

protein stabilization cocktail containing 15% glycerol, 11% trehalose, 8% mannitol and 8% sucrose was used as cryoprotectant.

Data were collected with a charge coupled device (CCD) detector at CHESS, NSLS and SSRL (beamlines F1 and F2, X12B and 1-5, respectively) and with a Mar Research image plate scanner at SSRL (beamlines 7-1 and 9-1). Multiwavelength anomalous diffraction (MAD) data were collected using the inverse beam mode after aligning the crystal with a major axis coincident with the rotation axis so that Bijvoet pairs could be measured simultaneously. Image plate data were reduced using the programs DENZO and SCALEPACK (Otwinowski and Minor, 1997) and CCD data were processed with the DPS, MOSFLM and CCP4 suite of programs. Mercury and osmium positions (three sites each) were readily identified by SHELXS (Sheldrick, 1997) and could later be confirmed in the isomorphous and anomalous difference Patterson maps. Iterative rounds of rejections performed with ENDHKL (Louis Sanchez, Cal. Tech.) in conjunction with SCALEPACK and local scaling were both critical for the identification of the heavy atoms. For MAD phasing an inhibitor, S-(2-(5((amidinothio)methyl)-2-thienyl)ethyl)isothioureia (Garvey *et al.*, 1994), was prepared with the sulfur atoms replaced with selenium. After 15 min, a solution of 2.401 g (0.011 mol) of ethyl 2-selenophenacetate in 5 ml of dichlormethane was added dropwise over several minutes. The mixture was poured into water and ice after 1 h and stirred for 30 min. The dichlormethane layer was washed with water, dried over sodium sulfate, and concentrated. The crude product was purified by silica gel chromatography with 10% ethyl acetate in petrolether to yield 1.77 g (65%) of 5-formyl-2-selenophenacetic acid ethyl ester intermediate. <sup>1</sup>H NMR (300 MHz, CDC13) 9.83 (formyl, 1H), 7.63-7.04 (aromatic, 2H), 4.19-4.17 (methyl, 5H), 3.86 (ethyl, 1H), 1.28-1.24 (methyl, 5H). To a 0 °C stirred suspension of 0.77 g (20.29 mmol) of lithium aluminium hydride (Aldrich) in 200 ml of tetrahydrofuran was added a solution of 2.0 g (8.65 mmol) of the intermediate prepared above in tetrahydrofuran. The suspension was stirred at 20 °C for 16 h, cooled to 0 °C, and the excess hydride was quenched by the careful addition of 0.8 ml of water, 0.8 ml of 1N sodium hydroxide solution, and 2.4 ml of water. The suspension was stirred with magnesium sulfate, filtered, concentrated, and purified by silica gel

chromatography with 50% ethyl acetate in petrolether. There was isolated 1.0 g (66%)<sup>3</sup> of diol intermediate (yellow oil). H NMR (300 MHz, CDC13) 7.97- 7.13 (aromatic, 2H), 4.83 (hydroxyl, 2H), 3.63 (ethyl, 5H), 1.63-1.42 (ethyl, 1H). A solution of this diol (1 g, 5.6 mmol) in dichlormethane (20 ml) at 0 oC was treated with 3.1 g (9.7 mmol) of carbon tribromide and 2.5 g (9.7 mmol) triphenylphosphine. The mixture was stirred at 20 oC for 4 h before 50 ml of petrolether was added. After 15 h, the solution was decanted from brown-colored solid, concentrated, and purified by silica gel chromatography (ethyl acetate/petrolether, 80:20) to yield 0.7 g (63%) of dibromide as an oil. A solution of 0.7 g (2.3 mmol) of dibromide and 1 g (8.12 mmol) of selenourea in 20 ml of absolute ethanol was refluxed for 2 h, cooled and concentrated to dryness. The crude solid was recrystallized from ethanol to yield 0.1 g (9.4%) of the bis-ISU as a yellow crystalline solid. H NMR (300 MHz, CDCL3) 9.25 (NH, 6H), 6.2 (aromatic, 2H), 4.22-4.15 (ethyl, 4H), 1.23-1.13 (ethyl, 4H).

*The preparation of 2-selenophenacetate:*

To a solution of 3.18 g ethylbromoacetate and 0.362 g of tin (IV) chloride in 10 ml of carbon disulfide at 0 oC was added dropwise over several minutes 2.5 g of selenophene in 1 ml CS<sub>2</sub>. The mixture was stirred at room temperature overnight, poured into water and ice, extracted by dichlommethane, washed by saturated solution of sodium hydrocarbonate, dried over sodium sulfate and concentrated. The crude product was purified by silica gel chromatography in dichlormethane to yield 0.7 g ethyl 2-sdenophenacetate (18.3%). <sup>1</sup>H NMR (300 MHz, DMSO) 7.23-7.2 (1H), 6.97-6.94(2H), 4.22-4.15 (ethyl 5H), 3.83 (methylen, 2H), 1.29-1.25 (methyl, 5H).

Once the structure was refined, it was evident that the inhibitor had not bound. One of the six sites initially assigned to selenium was the new zinc site and two others are most likely adducts of (CH<sub>3</sub>)<sub>2</sub>As to both Cys384 residues (one per monomer) from the cacodylate buffer used in crystallization. Since the crystallization solution contains excess reducing agents, the inventors attribute this chemistry to the reduction of dimethylarsenate (V) to dimethylarsenite (III) followed by reaction with Cys384 (Barber, 1932; Tsao and Maki, 1991). The three remaining sites initially thought to be selenium,



two near both Cys214 sulfurs and one near one Cys87, were much weaker and could not be confidently modeled as  $(\text{CH}_3)_2\text{As}$  sites in the final refined electron density map. Despite the incorrect assignment of the arsenic and zinc sites as selenium, their inclusion was essential for obtaining an interpretable electron density map. To the best of the inventors' knowledge this is the first study where arsenic atoms have been used successfully in phasing. Availability of heme iron positions, identified independently via anomalous scattering at the Fe edge, greatly facilitated the location of heavy atom sites. Heavy atom derivative screening and preliminary phase refinements were carried out with PHASES and visualized using XTALVIEW.

The final combined MAD and heavy atom refinement was done with SHARP (de La Fortelle and Bricogne, 1997) followed by density modification with either SOLOMON (Abrahams and Leslie, 1996) or DM. The latter calculation includes non-crystallographic symmetry (TICS) averaging. The resulting experimental MAD-heavy atom map at 2.35 Å was of sufficient quality to allow nearly all main chain atoms and 80% of the side chain atoms to be built into the model before the first round of refinement. Phase refinement with heavy atom derivatives alone did not produce an interpretable map. Heme iron positions, SHELXS, MAD phasing, and SHARP were a *sine qua non* for success in the structure solution.

Structural refinement was performed with XPLOR (Brünger, 1992) and SHELXL (Sheldrick and Schneider, 1997). Five percent of the data were set aside for free-R cross validation prior to any structural refinement. The protein model was built using TOM and improved with SigmaA-weighted  $2|F_{\text{obs}}| - |F_{\text{calc}}|$  and  $|F_{\text{obs}}| - |F_{\text{calc}}|$  maps iteratively with X-PLOR refinement. A bulk solvent correction was used in the final stages of the X-PLOR but not in the SHELXL refinement. The current model at 1.9 Å resolution includes 830 residues (residues 67 - 482 in molecule A; 69 - 482 in molecule B) and 591 waters. Residues 39-66 and 108-121 are disordered primarily due to the proline-rich nature of this region. Ramachandran plots generated with PROCHECK showed that 88.9% of the residues were in the most favored regions, 11% in additional

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allowed regions and 0.1% in disallowed regions. Solvent accessible surface area calculations were done with MSP.

Table 5

Data collection	Native	H4 free	Se edge	Se-peak	Se- remote	Se-EMP*	Se- OsO <sub>3</sub> (PY) <sub>2</sub> *
Wavelength (Å)	0.9798	1.08	0.9801	0.9794	0.9252	1.08	1.08
Resolution limits (Å)	1.9	2.1	2.3	2.3	2.3	2.3	3.0
Total observations	217,080	204,608	131,275	127,968	144,570	131,287	74,034
Unique observations	74,337	57,723	40,100	36,351	40,965	40,508	16,204
R <sub>sym</sub>	0.044	0.084	0.048	0.054	0.044	0.059	0.085
R <sub>sym</sub> (outer shell)	0.175	0.563	0.121	0.219	0.185	0.325	0.336
<I/σ>	19.3	7.7	16.9	15.3	17.1	9.8	8.9
<I/σ> (outer shell)	3.5	2.4	3.2	2.2	3.1	2.2	4.0
Completeness	0.965	0.996	0.962	0.988	0.985	0.977	0.808
Completeness (outer shell)	0.800	0.996	0.795	0.802	0.983	0.801	0.829
MAD phasing (20.0 - 2.35 Å)							
Number of sites			6				
Phasing power Iso/Ano			0.0/0.76	0.0/0.78	1.1/0.75		
R <sub>cutlis</sub> Iso/Ano			0.0/0.96	0.97/0.96	0.41/0.95		
MIRAS phasing							
Number of sites						6	5
R <sub>iso</sub>						0.157	0.173
R <sub>cutlis</sub>						0.89	0.92
Phasing power Iso/Ano						1.15/0.87	0.71/0.85
Overall FOM (MAD+MIRAS)			0.29				
			(2.35 Å)				
Refinement	Resolution (Å)	Protein	Waters	R-factor	R-free	Reflections	R.m.s. deviation <sup>§</sup>

Data collection	Native	H4 free	Se edge	Se-peak	Se-remote	Se-EMP*	Se-OsO <sub>3</sub> (PY) <sub>2</sub> *
		atoms					
X-PLOR (native)	30.0 - 1.9	6593	591	0.225 (F>2σF)	0.262	73.483 (F>2σF)	
SHELXL (native)	10.0 - 1.9	6593	591	0.207	0.278	70.029	0.007 Å 0.021 Å
X-PLOR (BH <sub>4</sub> free)	30.0 - 2.1	6593	336	0.187 (F>2σF)	0.247	48.347 (F>2σF)	0.007 Å 1.408°

$R_{\text{sym}} = \sum |I| - \langle I \rangle / \Sigma$ , where  $I$  is the observed intensity and  $\langle I \rangle$  the average intensity of multiple symmetry-related observations of that reflection.  $R_{\text{iso}} = \Sigma |F_{\text{PH}} - F_{\text{p}}| / \Sigma F_{\text{p}}$ .  $R_{\text{cullis}}$  ISO (acentric) = r.m.s. lack of closure / r.m.s. isomorphous difference (statistics from SHARP).  $R_{\text{cullis}}$  Ano = r.m.s. lack of closure / r.m.s. anomalous difference (statistics from SHARP). Phasing power = r.m.s. heavy atom structure factor / phase integrated lack of closure (statistics from SHARP). Overall FOM = overall figure of merit (from SHARP). R-free = R-factor calculated using 5% (3685 reflections) of the reflection data chosen randomly and set aside from the start of the refinement. EMP = ethylmercuric phosphate. OsO<sub>3</sub>Py<sub>2</sub> = osmium bis-pyridine. <sup>§</sup> r.m.s. deviations are defined as bond length and angular distances in SHELXL (Sheldrick and Schneider, 1997) and bond length and bond angle, respectively, in X-PLOR (Brünger, 1992).

The inventors report the 1.9 Å crystal structure of the dimeric heme domain of constitutive eNOS (Table 5), which maintains the catalytic site for NO<sup>o</sup> synthesis. The overall fold of the bovine eNOS heme domain (FIG. 1) is similar to that reported for the 2.6 Å structure of the iNOS heme domain dimer (Crane *et al.*, 1998). The quaternary structure of eNOS is characterized by a tightly packed dimer interface which buries 3000 Å<sup>2</sup> per subunit of solvent accessible surface (55% hydrophobic and 45% polar).

The inventors solved the structure of eNOS heme domain both in the presence and absence of BH<sub>4</sub> resulting in three major structural findings. First, the inventors found a novel ZnS<sub>4</sub> center (in both pterin-bound and -free structures) located at the bottom of the dimer interface (FIG. 1) with the metal tetrahedrally coordinated by two pairs of symmetry-related cysteine residues (FIG. 2) from each subunit.

Second, in the absence of BH<sub>4</sub>, the overall eNOS heme domain structure remains unchanged both in the tertiary topology and quaternary structure. These results sharply contrast with the conclusions of Crane *et al.*, (1998) who proposed that large conformational changes concomitant with BH<sub>4</sub> binding were necessary for inducible NOS dimerization. By comparison of the pterin-bound and -free structures, it is clear that the site preexists (FIG. 3) and does **not** form *via* an induced fit process. The pterin-free structure also does not show any major changes at the active site either in the substrate- or inhibitor (*S*-ethylisothiourrea, SEITU)-bound conformations.

Third, in addition to the new ZnS<sub>4</sub> center, the most striking and novel finding is the identification of an L-Arg bound to the pterin site in the absence of BH<sub>4</sub> (FIG. 3A and FIG. 3D). The mode of L-Arg interaction at the pterin site surprisingly mimics that entertained by BH<sub>4</sub> itself. Two crucial H-bonds, one between a guanidino N with the heme propionate and that between the primary amino group and Ser 104 are strictly conserved (FIG. 3D). Moreover, the planar guanidinium group is sandwiched between two aromatic groups, one from each monomer, exactly as in the BH<sub>4</sub> complex. Solvent interactions also are similar to the BH<sub>4</sub> complex. The affinity L-Arg must be great since

no exogenous L-Arg was added during crystallization. The specificity of L-Arg recognition at the pterin site appears to require both the guanidino function and the primary amino group since SEITU was unable to displace L-Arg from the pterin site. The relevance of these findings is discussed in greater detail herein above.

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\* \* \*

All of the compositions and/or methods disclosed and claimed herein can be made and executed without undue experimentation in light of the present disclosure. While the compositions and methods of this invention have been described in terms of preferred  
10 embodiments, it will be apparent to those of skill in the art that variations may be applied to the compositions and/or methods and in the steps or in the sequence of steps of the method described herein without departing from the concept, spirit and scope of the invention. More specifically, it will be apparent that certain agents which are both chemically and physiologically related may be substituted for the agents described herein  
15 while the same or similar results would be achieved. All such similar substitutes and modifications apparent to those skilled in the art are deemed to be within the spirit, scope and concept of the invention as defined by the appended claims.

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The following references, to the extent that they provide exemplary procedural or other details supplementary to those set forth herein, are specifically incorporated herein by reference.

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**WHAT IS CLAIMED IS:**

1. A method for the structural analysis of endothelial nitric oxide synthase comprising:

- 5 a) subcloning a gene encoding the endothelial nitric oxide synthase in an expression vector;
- b) obtaining expression of the endothelial nitric oxide synthase protein from the vector;
- c) purifying the endothelial nitric oxide synthase protein;
- 10 d) preparing an endothelial nitric oxide synthase protein sample amenable for crystallization;
- e) crystallizing the endothelial nitric oxide synthase protein sample; and
- f) performing a three-dimensional structural analysis of the endothelial nitric oxide synthase by x-ray crystallography.

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2. The method of claim 1, wherein the endothelial nitric oxide synthase protein expressed is a variant endothelial nitric oxide synthase protein.

20

3. The method of claim 1, wherein the crystallizing comprises practicing a sitting drop vapor-diffusion method.

4. The method of claim 1, wherein the crystallizing is performed in the presence of tetrahydrobiopterin.

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5. The method of claim 1, wherein the crystallizing is performed in the absence of tetrahydrobiopterin.

6. The method of claim 1, wherein the x-ray crystallography is performed in the presence of tetrahydrobiopterin.

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7. The method of claim 1, wherein the x-ray crystallography is performed in the absence of tetrahydrobiopterin.

8. A method of structural analysis to determine the binding of pterin to endothelial nitric oxide synthase comprising:

- a) determining the crystal structure of a dimeric heme domain of the endothelial nitric oxide synthase in the presence of the pterin; and
  - b) determining the crystal structure of a dimeric heme domain of the endothelial nitric oxide synthase in the absence of the pterin;
- and comparing the crystal structures.

9. The method of claim 8, wherein the pterin is tetrahydrobiopterin.

10. The method of claim 9, wherein the tetrahydrobiopterin is (1'R,2'S,6R)-5,6,7,8-tetrahydrobiopterin.

11. The method of claim 8, wherein the crystal structure is determined at a resolution of between about 1.9 Å to about 2.1 Å.

12. A method for screening and identifying small molecule modulators of endothelial nitric oxide synthase proteins comprising:

- a) providing a pterin-free endothelial nitric oxide synthase structure;
- b) screening the small molecule modulators for their ability to bind to a pterin-binding site of the endothelial nitric oxide synthase ; and
- c) performing assays to determine the ability of the small molecule modulators to modulate the activity of endothelial nitric oxide synthase.

13. The method of claim 12, wherein the small molecule modulator inhibits endothelial nitric oxide synthase.

14. The method of claim 12, wherein the small molecule modulator activates endothelial nitric oxide synthase.
15. The method of claim 12, wherein the endothelial nitric oxide synthase protein expressed is a variant endothelial nitric oxide synthase protein.
16. The method of claim 12, wherein the pterin is tetrahydrobiopterin.
17. The method of claim 16, wherein the tetrahydrobiopterin is (1'R,2'S,6R)-5,6,7,8-tetrahydrobiopterin.
18. The method of claim 12, wherein the small molecule modulators are molecules and chemical-fragments from chemical-fragment libraries.
19. The method of claim 12, wherein the screening is performed by computerized methods.
20. The method of claim 12, wherein the assays are performed *in vitro* or *in vivo*.
21. A method for identifying drugs against diseased states in which nitric oxide signaling is defective or insufficient comprising:
- a) providing a tetrahydrobiopterin-free endothelial nitric oxide synthase structure;
  - b) screening the drugs for their ability to bind the tetrahydrobiopterin binding site; and
  - c) performing assays to determine the ability of the drugs to activate the endothelial nitric oxide synthase.
22. The method of claim 21, wherein the diseased states include impaired neurotransmission; impaired insulin release; impaired penile erection; impaired vasorelaxation; and impaired oxygen detection.

23. Endothelial nitric oxide synthase structure, obtained by the process comprising:
- a) subcloning a gene encoding the endothelial nitric oxide synthase in an expression vector;
  - 5 b) obtaining expression of the endothelial nitric oxide synthase protein from the vector;
  - c) purifying the endothelial nitric oxide synthase protein;
  - d) preparing an endothelial nitric oxide synthase protein sample amenable for crystallization;
  - 10 e) crystallizing the endothelial nitric oxide synthase protein sample.
  - f) performing a three-dimensional structural analysis of the endothelial nitric oxide synthase by x-ray crystallography.
24. A nitric oxide synthase obtained according to the method of claim 1.
- 15 25. A method for screening and identifying a candidate substance with the ability to inhibit endothelial nitric oxide synthase comprising:
- a) obtaining a cell with endothelial nitric oxide synthase activity;
  - b) admixing the candidate substance with the cell; and
  - 20 c) determining the ability of the candidate substance to inhibit the endothelial nitric oxide synthase activity of the cell.
26. The method of claim 25, wherein the candidate substance is a small molecule modulator of endothelial nitric oxide synthase.
- 25 27. A method for screening and identifying a candidate substance with the ability to inhibit endothelial nitric oxide synthase comprising:
- a) obtaining a purified endothelial nitric oxide synthase;
  - b) admixing the endothelial nitric oxide synthase with the candidate
  - 30 substance; and

- c) performing X-ray crystallography analysis to determine the binding of the candidate substance.

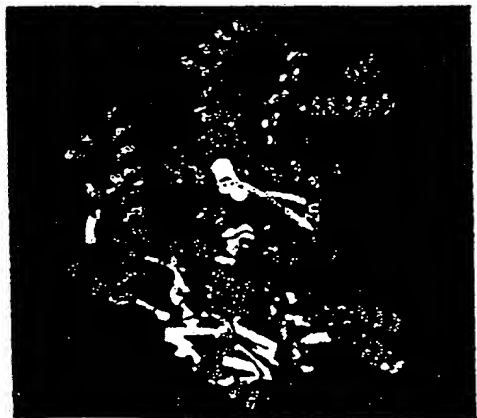


Figure 1



Figure 2

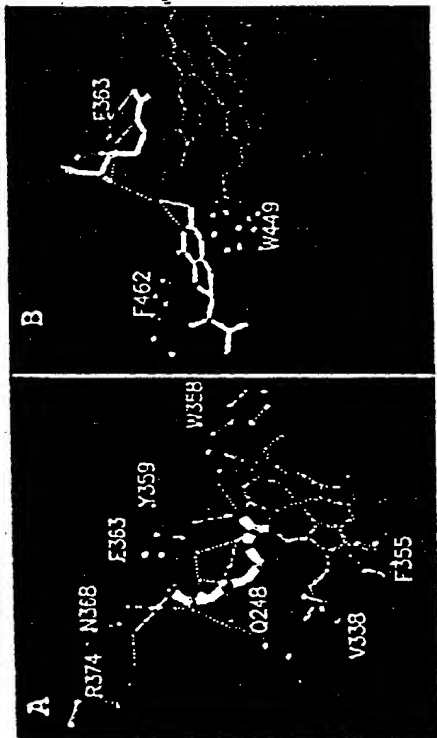


Figure 3

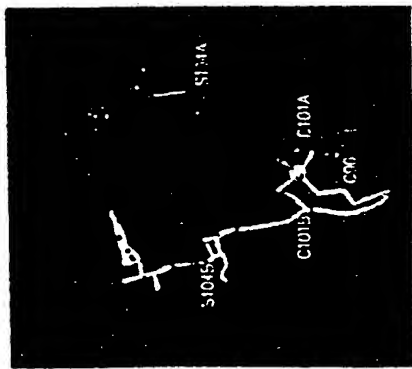


Figure 4

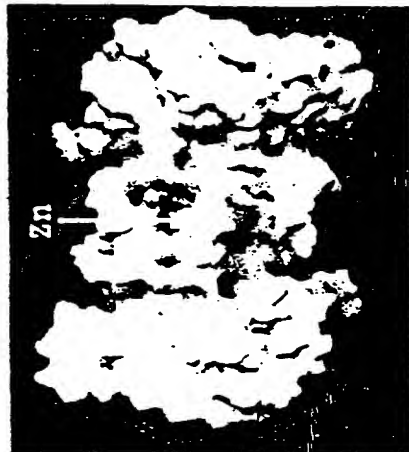
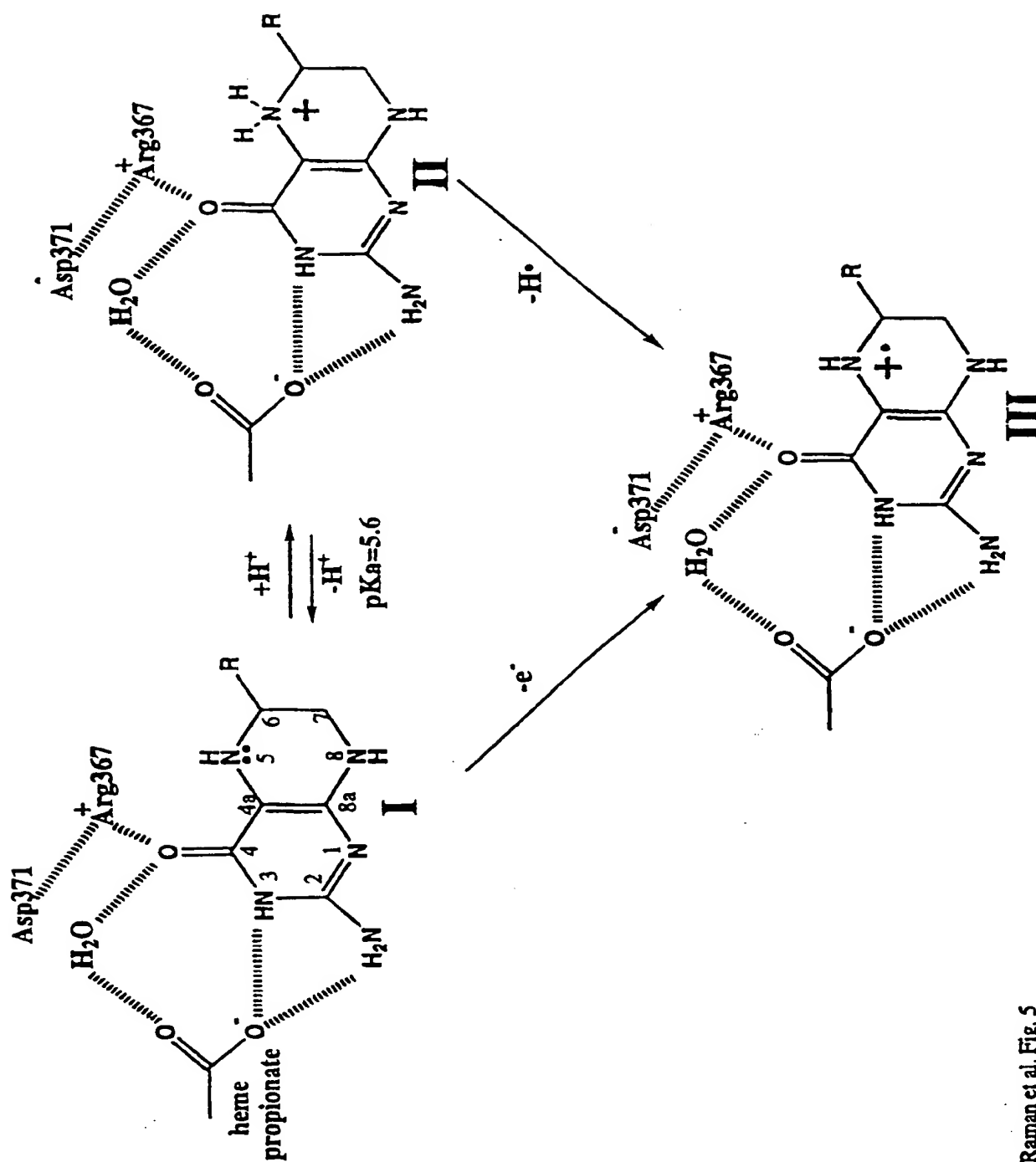


Figure 5





# INTERNATIONAL SEARCH REPORT

Int. .tional Application No  
PCT/US 99/30707

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> IPC 7 C12N15/53 C12N9/02 C12Q1/26		
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<b>B. FIELDS SEARCHED</b> Minimum documentation searched (classification system followed by classification symbols) IPC 7 C12N C12Q		
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X	WO 93 18156 A (GEN HOSPITAL CORP) 16 September 1993 (1993-09-16)	24
Y	the whole document	1-11
-/-		
<div style="display: flex; justify-content: space-between;"> <span><input checked="" type="checkbox"/> Further documents are listed in the continuation of box C.</span> <span><input checked="" type="checkbox"/> Patent family members are listed in annex.</span> </div>		
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Date of the actual completion of the international search  <div style="text-align: center; font-weight: bold;">9 May 2000</div>		Date of mailing of the international search report  <div style="text-align: center; font-weight: bold;">23/05/2000</div>
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3018		Authorized officer  <div style="text-align: center; font-weight: bold;">Hornig, H</div>

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Int. l. Application No  
PCT/US 99/30707

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
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Y	the whole document	1-11
X	WO 97 08299 A (UNIV TEXAS ;MASTERS BETTIE SUE (US); ROMAN LINDA J (US); SHETA ESS) 6 March 1997 (1997-03-06)	24
Y	claims 1-41	1-11
X	WO 98 02555 A (SALERNO JOHN C) 22 January 1998 (1998-01-22) page 54, line 9 - line 18; claims 31,32	12-18,20
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Information on patent family members

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9318156 A	16-09-1993	AU 3789193 A	05-10-1993
US 5498539 A	12-03-1996	NONE	
WO 9708299 A	06-03-1997	US 5919682 A AU 6910296 A	06-07-1999 19-03-1997
WO 9802555 A	22-01-1998	AU 3885497 A EP 0938567 A	09-02-1998 01-09-1999
WO 9641885 A	27-12-1996	US 5744340 A AU 6149296 A CA 2224089 A EP 0832246 A JP 11507830 T	28-04-1998 09-01-1997 27-12-1996 01-04-1998 13-07-1999

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Int. .tional Application No  
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IPC 7 C12N15/53 C12N9/02 C12Q1/26

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**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
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Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

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Date of the actual completion of the international search

9 May 2000

Date of mailing of the international search report

23/05/2000

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Hornig, H

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## PCT

## INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference <b>UTFK336P</b>	<b>FOR FURTHER ACTION</b> see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. <b>PCT/US 99/ 30707</b>	International filing date (day/month/year) <b>22/12/1999</b>	(Earliest) Priority Date (day/month/year) <b>22/12/1998</b>
Applicant <b>BOARD OF REGENTS, THE UNIVERSITY OF TEXAS SYSTEM</b>		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 4 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

## 1. Basis of the report

- a. With regard to the language, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

☐ the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

- b. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international search was carried out on the basis of the sequence listing:

☐ contained in the international application in written form.

☐ filed together with the international application in computer readable form.

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☐ the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. ☐ Certain claims were found unsearchable (See Box I).

3. ☐ Unity of invention is lacking (see Box II).

## 4. With regard to the title,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

## 5. With regard to the abstract,

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## 6. The figure of the drawings to be published with the abstract is Figure No.

☐ as suggested by the applicant.

☒ because the applicant failed to suggest a figure.

☐ because this figure better characterizes the invention.

2

☐ None of the figures.

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 99/30707

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PCT/US 99/30707

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 498 539 A (HARRISON DAVID G ET AL) 12 March 1996 (1996-03-12)	24
Y	the whole document	1-11
X	WO 97 08299 A (UNIV TEXAS ;MASTERS BETTIE SUE (US); ROMAN LINDA J (US); SHETA ESS) 6 March 1997 (1997-03-06)	24
Y	claims 1-41	1-11
X	WO 98 02555 A (SALERNO JOHN C) 22 January 1998 (1998-01-22) page 54, line 9 - line 18; claims 31,32	12-18,20
Y	B.R. CRANE ET AL.: "Structure of nitric acid synthase oxygenase dimer with pterin and substrate" SCIENCE, vol. 279, 27 March 1998 (1998-03-27), pages 2121-2126, XP002137146 AAAS, WASHINGTON, DC, US cited in the application the whole document	1-11,23, 24
Y	B.R. CRANE ET AL.: "The structure of nitric oxide synthase oxygenase domain and inhibitor complexes" SCIENCE, vol. 278, 17 October 1997 (1997-10-17), pages 425-431, XP002137147 AAAS, WASHINGTON, DC, US the whole document	1-11,23, 24
A	T.L. POULOS ET AL.: "NO news is good news" STRUCTURE, vol. 6, 15 March 1998 (1998-03-15), pages 255-258, XP000906922 CURRENT BIOLOGY LTD, PHILADELPHIA, US the whole document	1-11
A	WO 96 41885 A (SCHERING CORP) 27 December 1996 (1996-12-27) the whole document	
P,X	C.S. RAMAN ET AL.: "Crystal structure of constitutive endothelial nitric oxide synthase: A paradigm for pterin function involving a novel metal center" CELL, vol. 95, 23 December 1998 (1998-12-23), pages 939-950, XP002137148 CELL PRESS, CAMBRIDGE, MA, US; the whole document	1-11,23, 24
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## INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 99/30707

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, X	<p>FISCHMANN THIERRY O ET AL: "Structural characterization of nitric oxide synthase isoforms reveals striking active-site conservation."</p> <p>NATURE STRUCTURAL BIOLOGY MARCH, 1999, vol. 6, no. 3, March 1999 (1999-03), pages 233-242, XP002137149</p> <p>ISSN: 1072-8368</p> <p>the whole document</p> <p>-----</p>	1-11, 23, 24

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 99/30707

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
WO 9318156	A	16-09-1993	AU	3789193 A	05-10-1993
US 5498539	A	12-03-1996	NONE		
WO 9708299	A	06-03-1997	US	5919682 A	06-07-1999
			AU	6910296 A	19-03-1997
WO 9802555	A	22-01-1998	AU	3885497 A	09-02-1998
			EP	0938567 A	01-09-1999
WO 9641885	A	27-12-1996	US	5744340 A	28-04-1998
			AU	6149296 A	09-01-1997
			CA	2224089 A	27-12-1996
			EP	0832246 A	01-04-1998
			JP	11507830 T	13-07-1999

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# PCT REQUEST

The undersigned requests that the present  
international application be processed  
according to the Patent Cooperation Treaty

For receiving Office use only

International Application No.

International Filing Date

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference  
(if desired) (12 characters maximum) UTFK336P

**Box No. I TITLE OF INVENTION**  
STRUCTURAL BASIS FOR PTERIN FUNCTION IN NITRIC OXIDE SYNTHASE

**Box No. II APPLICANT**

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

BOARD OF REGENTS, THE UNIVERSITY OF TEXAS SYSTEM  
201 W. 7th St.  
Austin, TX 78701  
US

☐ This person is also inventor.

Telephone No.

Facsimile No.

Teleprinter No.

State (that is, country) of nationality: US

State (that is, country) of residence: US

This person is applicant ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

**Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)**

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

MASTERS, Bettie Sue S.  
16534 Hidden View  
San Antonio, TX 78232  
US

This person is:

☐ applicant only

☒ applicant and inventor

☐ inventor only (If this check-box is marked, do not fill in below.)

State (that is, country) of nationality: US

State (that is, country) of residence: US

This person is applicant ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on a continuation sheet.

**Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE**

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and address: (Family name followed by give name; for a legal entity, full official designation. The address must include postal code and name of country.)

WILSON, MARK B.  
ARNOLD WHITE & DURKEE  
750 Bering Drive  
Houston, TX 77057-2198  
United States of America

Telephone No. (713) 787-1400

Facsimile No. 713-787-1440

Teleprinter No.

☐ Address for correspondence: Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

## Continuation of Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTORS

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Name and address: <i>(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)</i>  MARTASEK, Pavel 7531 Pipers Lane San Antonio, TX 78251 US		This person is:  <input type="checkbox"/> applicant only <input checked="" type="checkbox"/> applicant and inventor <input type="checkbox"/> inventor only <i>(If this check-box is marked, do not fill in below.)</i>
State <i>(that is, country)</i> of nationality: CZ	State <i>(that is, country)</i> of residence: US	
This person is applicant for the purposes of: <input type="checkbox"/> all designated States <input type="checkbox"/> all designated States except the United States of America <input checked="" type="checkbox"/> the United States of America only <input type="checkbox"/> the States indicated in the Supplemental Box		
Name and address: <i>(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)</i>  ROMAN, Linda J. 2814 Squaw Creek San Antonio, TX 78230 US		This person is:  <input type="checkbox"/> applicant only <input checked="" type="checkbox"/> applicant and inventor <input type="checkbox"/> inventor only <i>(If this check-box is marked, do not fill in below.)</i>
State <i>(that is, country)</i> of nationality: US	State <i>(that is, country)</i> of residence: US	
This person is applicant for the purposes of: <input type="checkbox"/> all designated States <input type="checkbox"/> all designated States except the United States of America <input checked="" type="checkbox"/> the United States of America only <input type="checkbox"/> the States indicated in the Supplemental Box		
Name and address: <i>(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)</i>  KRAL, Vladimir Na Kozacce 8/9275 120 00 Prahal Czech Republic		This person is:  <input type="checkbox"/> applicant only <input checked="" type="checkbox"/> applicant and inventor <input type="checkbox"/> inventor only <i>(If this check-box is marked, do not fill in below.)</i>
State <i>(that is, country)</i> of nationality: CZ	State <i>(that is, country)</i> of residence: CZ	
This person is applicant for the purposes of: <input type="checkbox"/> all designated States <input type="checkbox"/> all designated States except the United States of America <input checked="" type="checkbox"/> the United States of America only <input type="checkbox"/> the States indicated in the Supplemental Box		
Name and address: <i>(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)</i>  POULOS, Thomas L. 48 Urey Court Irvine, CA 92612 US		This person is:  <input type="checkbox"/> applicant only <input checked="" type="checkbox"/> applicant and inventor <input type="checkbox"/> inventor only <i>(If this check-box is marked, do not fill in below.)</i>
State <i>(that is, country)</i> of nationality:	State <i>(that is, country)</i> of residence: US	
This person is applicant for the purposes of: <input type="checkbox"/> all designated States <input type="checkbox"/> all designated States except the United States of America <input checked="" type="checkbox"/> the United States of America only <input type="checkbox"/> the States indicated in the Supplemental Box		
<input checked="" type="checkbox"/> Further applicants and/or (further) inventors are indicated on a continuation sheet.		



Continuation of Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTORS	
<i>If none of the following sub-boxes is used, this sheet is not to be included in the request.</i>	
Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)  RAMAN, C.S.	This person is:  <input type="checkbox"/> applicant only  <input checked="" type="checkbox"/> applicant and inventor  <input type="checkbox"/> inventor only (If this check-box is marked, do not fill in below.)
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This person is applicant for the purposes of: <input type="checkbox"/> all designated States <input type="checkbox"/> all designated States except the United States of America <input checked="" type="checkbox"/> the United States of America only <input type="checkbox"/> the States indicated in the Supplemental Box	
Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)	This person is:  <input type="checkbox"/> applicant only  <input type="checkbox"/> applicant and inventor  <input type="checkbox"/> inventor only (If this check-box is marked, do not fill in below.)
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Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)	This person is:  <input type="checkbox"/> applicant only  <input type="checkbox"/> applicant and inventor  <input type="checkbox"/> inventor only (If this check-box is marked, do not fill in below.)
State (that is, country) of nationality:	State (that is, country) of residence:
This person is applicant for the purposes of: <input type="checkbox"/> all designated States <input type="checkbox"/> all designated States except the United States of America <input type="checkbox"/> the United States of America only <input type="checkbox"/> the States indicated in the Supplemental Box	
<input type="checkbox"/> Further applicants and/or (further) inventors are indicated on a continuation sheet.	

**Box No. V DESIGNATION OF STATES**

The following designations are hereby made under Rule 4.9(a) (mark the applicable check-boxes; at least one must be marked):

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| <input checked="" type="checkbox"/> BA Bosnia and Herzegovina                | <input checked="" type="checkbox"/> MD Republic of Moldova                       |
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| <input checked="" type="checkbox"/> HU Hungary                               | <input checked="" type="checkbox"/> UA Ukraine                                   |
| <input checked="" type="checkbox"/> ID Indonesia                             | <input checked="" type="checkbox"/> UG Uganda                                    |
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| <input checked="" type="checkbox"/> IN India                                 | <input checked="" type="checkbox"/> UZ Uzbekistan                                |
| <input checked="" type="checkbox"/> IS Iceland                               | <input checked="" type="checkbox"/> VN Viet Nam                                  |
| <input checked="" type="checkbox"/> JP Japan                                 | <input checked="" type="checkbox"/> YU Yugoslavia                                |
| <input checked="" type="checkbox"/> KE Kenya                                 | <input checked="" type="checkbox"/> ZA South Africa                              |
| <input checked="" type="checkbox"/> KG Kyrgyzstan                            | <input checked="" type="checkbox"/> ZW Zimbabwe                                  |
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| <input checked="" type="checkbox"/> KR Republic of Korea                     |  |
| <input checked="" type="checkbox"/> KZ Kazakstan                             |  |
| <input checked="" type="checkbox"/> LC Saint Lucia                           |  |
| <input checked="" type="checkbox"/> LK Sri Lanka                             |  |

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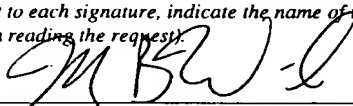
**Precautionary Designation Statement:** In addition to the designations made above, the applicant also makes under Rule 4.9(b) all other designations which would be permitted under the PCT except the designations(s) indicated in the Supplemental Box as being excluded from the scope of this statement. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. (Confirmation of a designation consists of the filing of a notice specifying that designation and the payment of the designation and confirmation fees. Confirmation must reach the receiving Office within the 15-month time limit.)

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1. If, in any of the Boxes, the space is insufficient to furnish all the information: in such case, write "Continuation of Box No. ..." [indicate the number of the Box] and furnish the information in the same manner as required according to the captions of the Box in which the space was insufficient, in particular:

- (i) if more than two persons are involved as applicants and/or inventors and no "continuation sheet" is available: in such case, write "Continuation of Box No. III" and indicate for each additional person the same type of information as required in Box No. III. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below;
  - (ii) if, in Box No. II or in any of the sub-boxes of Box No. III, the indication "the States indicated in the Supplemental Box" is checked: in such case, write "Continuation of Box No. II" or "Continuation of Box No. III" or "Continuation of Boxes No. II and No. III" (as the case may be), indicate the name of the applicant(s) involved and, next to (each) such name, the State(s) (and/or, where applicable, ARIPO, Eurasian, European or OAPI patent) for the purposes of which the named person is applicant;
  - (iii) if, in Box No. II or in any of the sub-boxes of Box No. III, the inventor or the inventor/applicant is not inventor for the purposes of all designated States or for the purposes of the United States of America: in such case, write "Continuation of Box No. II" or "Continuation of Box No. III" or "Continuation of Boxes No. II and No. III" (as the case may be), indicate the name of the inventor(s) and, next to (each) such name, the State(s) (and/or, where applicable, ARIPO, Eurasian, European or OAPI patent) for the purposes of which the named person is inventor;
  - (iv) if, in addition to the agent(s) indicated in Box No. IV, there are further agents: in such case, write "Continuation of Box No. IV" and indicate for each further agent the same type of information as required in Box No. IV;
  - (v) if, in Box No. V, the name of any State (or OAPI) is accompanied by the indication "patent of addition," or "certificate of addition," or if, in Box No. V, the name of the United States of America is accompanied by an indication "continuation" or "continuation-in-part": in such case, write "Continuation of Box V" and the name of each State involved (or OAPI), and after the name of each such State (or OAPI), the number of the parent title or parent application and the date of grant of the parent title or filing of the parent application;
  - (vi) if, in Box No. VI, there are more than three earlier applications whose priority is claimed: in such case, write "Continuation of Box No. VI" and indicate for each additional earlier application the same type of information as required in Box No. VI;
  - (vii) if, in Box No. VI, the earlier application is an ARIPO application: in such case, write "Continuation of Box VI", specify the number of the item corresponding to that earlier application and indicate at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed.
2. If, with regard to the precautionary designation statement contained in Box No. V, the applicant wishes to exclude any State(s) from the scope of that statement: in such case, write "Designation(s) excluded from precautionary designation statement" and indicate the name or two-letter code of each State so excluded.
3. If the applicant claims, in respect of any designated Office, the benefits, of provisions of the national law concerning non-prejudicial disclosures or exceptions to lack of novelty: in such case, write "Statement concerning non-prejudicial disclosures or exceptions to lack of novelty: and furnish that statement below.

CONTINUATION OF BOX V, U.S. Serial No. 60/113.204 filed 22 December 1998 (22.12.98)

<b>Box No. VI PRIORITY CLAIM</b>		<input type="checkbox"/> Further priority claims are indicated in the Supplemental Box		
<b>Where earlier application is:</b>				
Filing Date of earlier application (day/month/year)	Number of earlier application	national application: country	regional application:* regional Office	international application: receiving Office
item (1) 22 DECEMBER 1998 (22.12.98)	60/113.204	US		
item (2)				
item (3)				
<input checked="" type="checkbox"/> The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) (only if the earlier application was filed with the Office which for the purposes of the present international application is the receiving Office) identified above as item(s): <u>EP</u> <i>* Where the earlier application is an ARIPO application, it is mandatory to indicate in the Supplemental Box at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed (Rule 4.10(b)(ii)). See Supplemental Box.</i>				
<b>BOX No. VII INTERNATIONAL SEARCHING AUTHORITY</b>				
Choice of International Searching Authority (ISA) (If two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used): ISA EPO		Request to use results of earlier search; reference to that search (if an earlier search has been carried out by or requested from the International Searching Authority): Date (day/month/year)      Number      Country (or regional Office):		
<b>BOX No. VIII CHECK LIST; LANGUAGE OF FILING</b>				
This international application contains the following number of sheets: request : 5 sheets description (excluding sequence listing part) : 47 sheets claims : 5 sheets abstract : 1 sheets drawings : 2 sheets sequence listing part of description : _____ sheets Total number of sheets: 60 sheets		This international application is accompanied by the item(s) marked below: 1. <input checked="" type="checkbox"/> fee calculation sheet 2. <input type="checkbox"/> separate signed power of attorney 3. <input type="checkbox"/> copy of general power of attorney; reference number, if any: 4. <input type="checkbox"/> statement explaining lack of signature 5. <input type="checkbox"/> priority document(s) identified in Box No. VI as item(s): 6. <input type="checkbox"/> translation of international application into (language): 7. <input type="checkbox"/> separate indications concerning deposited microorganisms or other biological material 8. <input type="checkbox"/> nucleotide and/or amino acid sequence listing in computer readable form 9. <input checked="" type="checkbox"/> other (specify): post card		
Figure of the drawings which should accompany the abstract:		Language of filing of the international application: English		
<b>Box No. IX SIGNATURE OF APPLICANT OR AGENT</b>				
Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request). <div style="display: flex; justify-content: space-between; align-items: flex-end;"> <div style="text-align: center;">             Mark B. Wilson, Applicant's Agent         </div> <div style="text-align: center;"> <u>12/22/99</u>            Date         </div> </div>				

<b>For receiving Office use only</b>		2. Drawings:  [ ] received:  [ ] not received
1. Date of actual receipt of the purported international application:		
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:		
4. Date of timely receipt of the required corrections under PCT Article 11(2):		
5. International Searching Authority (if two or more are competent):      ISA/	6. [ ] Transmittal of search copy-delayed until search fee is paid	

<b>For International Bureau use only</b>
Date of receipt of the record copy by the International Bureau:

## PATENT COOPERATION TREATY

PCT

NOTIFICATION OF RECEIPT OF  
RECORD COPY

(PCT Rule 24.2(a))

From the INTERNATIONAL BUREAU

To:

WILSON, Mark, B. **REC'D HOWREY SIMON ARNOLD & WHITE**  
 Arnold White & Durkee  
 750 Bering Drive  
 Houston, TX 77057-2198  
 ÉTATS-UNIS D'AMÉRIQUE **HOUSTON DOCKETING DEPT.**

MAR 16 2000

Date of mailing (day/month/year) 02 March 2000 (02.03.00)	IMPORTANT NOTIFICATION
Applicant's or agent's file reference UTFK336P	International application No. PCT/US99/30707

The applicant is hereby notified that the International Bureau has received the record copy of the international application as detailed below.

Name(s) of the applicant(s) and State(s) for which they are applicants:

BOARD OF REGENTS, THE UNIVERSITY OF TEXAS SYSTEM (for all designated States  
except US)

MASTERS, Bettie, Sue, S. et al (for US)

International filing date : 22 December 1999 (22.12.99)

Priority date(s) claimed : 22 December 1998 (22.12.98)

Date of receipt of the record copy  
by the International Bureau : 18 February 2000 (18.02.00)

List of designated Offices :

AP : GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW

EA : AM, AZ, BY, KG, KZ, MD, RU, TJ, TM

EP : AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE

OA : BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG

National : AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB,  
 GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK,  
 MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA,  
 ZW

FULBRIGHT & JAWORSKI LLP  
 AUSTIN, TEXAS

MAR 17 2000

RECEIVED

DOCKETED none  
 DATE Chc  
 INITIALS Chc

DOCKETED ☐ UPDATED ☐

Previously ☐ Not Required ☒

Appl. Info ☐

Reg./Exam. Info ☐

Action Required: ☐

Date Recd/Exam: ☐

By: Jim Checked JP

The International Bureau of WIPO  
 34, chemin des Colombettes  
 1211 Geneva 20, Switzerland

Facsimile No. (41-22) 740.14.35

Authorized officer:

S. De Michiel

Telephone No. (41-22) 338.83.38

DOCKETED ☐ UPDATED ☐  
Previously ☒ Not Required  
App. Info  
Reg./Class. Info  
Action Required

PCT/US99/30707

PATENT COOPERATION TREATY

WIM/STW

PCT

RECEIVED  
F & J  
AUSTIN INTL

From the INTERNATIONAL BUREAU

NOTIFICATION CONCERNING  
SUBMISSION OR TRANSMITTAL  
OF PRIORITY DOCUMENT

(PCT Administrative Instructions, Section 411)

To:  
WILSON, Mark, B.  
Arnold White & Durkee  
750 Bering Drive  
Houston, TX 77057-2198  
ETATS-UNIS D'AMERIQUE  
REC'D HOWREY SIMON ARNOLD & WHITE  
APR 12 2000

HOUSTON DOCKETING DEPT.

Date of mailing (day/month/year) 24 March 2000 (24.03.00)	
Applicant's or agent's file reference UTFK336P	IMPORTANT NOTIFICATION
International application No. PCT/US99/30707	International filing date (day/month/year) 22 December 1999 (22.12.99)
International publication date (day/month/year) Not yet published	Priority date (day/month/year) 22 December 1998 (22.12.98)
Applicant BOARD OF REGENTS, THE UNIVERSITY OF TEXAS SYSTEM et al	

- The applicant is hereby notified of the date of receipt (except where the letters "NR" appear in the right-hand column) by the International Bureau of the priority document(s) relating to the earlier application(s) indicated below. Unless otherwise indicated by an asterisk appearing next to a date of receipt, or by the letters "NR", in the right-hand column, the priority document concerned was submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b).
- This updates and replaces any previously issued notification concerning submission or transmittal of priority documents.
- An asterisk(\*) appearing next to a date of receipt, in the right-hand column, denotes a priority document submitted or transmitted to the International Bureau but not in compliance with Rule 17.1(a) or (b). In such a case, the attention of the applicant is directed to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.
- The letters "NR" appearing in the right-hand column denote a priority document which was not received by the International Bureau or which the applicant did not request the receiving Office to prepare and transmit to the International Bureau, as provided by Rule 17.1(a) or (b), respectively. In such a case, the attention of the applicant is directed to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

Priority date	Priority application No.	Country or regional Office or PCT receiving Office	Date of receipt of priority document
22 Dec 1998 (22.12.98)	60/113,204	US	14 Marc 2000 (14.03.00)

FULBRIGHT & JAWORSKI LLP  
AUSTIN, TEXAS

APR 14 2000

DOCKETED  
DATE  
INITIALS

RECEIVED

The International Bureau of WIPO  
34, chemin des Colombettes  
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 740.14.35

Authorized officer

Tessadel PAMPLIEGA

Telephone No. (41-22) 338.83.38

RECEIVED  
NOTI

(PCT Rule 92bis.1 and  
Administrative Instructions, Section 422)

To:

WILSON, Mark, B.  
Fulbright & Jaworski L.L.P.  
600 Congress Avenue  
Suite 2400  
Austin, TX 78701  
ETATS-UNIS D'AMERIQUE

<b>Date of mailing (day/month/year)</b> 14 June 2000 (14.06.00)	ETATS-UNIS D AMERIQUE
<b>Applicant's or agent's file reference</b> UTFK336P	<b>IMPORTANT NOTIFICATION</b>
<b>International application No.</b> PCT/US99/30707	<b>International filing date (day/month/year)</b> 22 December 1999 (22.12.99)

<b>1. The following indications appeared on record concerning:</b> <input type="checkbox"/> the applicant <input type="checkbox"/> the inventor <input checked="" type="checkbox"/> the agent <input type="checkbox"/> the common representative					
<b>Name and Address</b> WILSON, Mark, B. Arnold White & Durkee 750 Bering Drive Houston, TX 77057-2198 United States of America		<b>State of Nationality</b>  		<b>State of Residence</b>  	
		<b>Telephone No.</b> 713 787 1400			
		<b>Facsimile No.</b> 713 787 1440			
		<b>Teleprinter No.</b>  			
<b>2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:</b> <input type="checkbox"/> the person <input type="checkbox"/> the name <input checked="" type="checkbox"/> the address <input type="checkbox"/> the nationality <input type="checkbox"/> the residence					
<b>Name and Address</b> WILSON, Mark, B. Fulbright & Jaworski L.L.P. 600 Congress Avenue Suite 2400 Austin, TX 78701 United States of America		<b>State of Nationality</b>  		<b>State of Residence</b>  	
		<b>Telephone No.</b> 512 418 3000			
		<b>Facsimile No.</b> 512 474 7577			
		<b>Teleprinter No.</b>  			
<b>3. Further observations, if necessary:</b>					
<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="text-align: left;">           DOCKETED            DATE <u>Noted -</u>            INITIALS <u>CLC</u> </div> <div style="text-align: right;"> <b>RECEIVED</b>  <b>F &amp; J</b>  <b>AUSTIN INTL</b>    <b>JUL 24 2000</b> </div> </div>					
<b>4. A copy of this notification has been sent to:</b> <div style="display: flex; justify-content: space-between;"> <div> <input checked="" type="checkbox"/> the receiving Office  <input type="checkbox"/> the International Searching Authority  <input type="checkbox"/> the International Preliminary Examining Authority         </div> <div> <input type="checkbox"/> the designated Offices concerned  <input type="checkbox"/> the elected Offices concerned  <input type="checkbox"/> other:         </div> </div>					

**The International Bureau of WIPO**  
34, chemin des Colombettes  
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer

S. De Michiel

Telephone No.: (41-22) 338.83.38

## PATENT COOPERATION TREATY

PCT

NOTIFICATION OF THE RECORDING  
OF A CHANGE(PCT Rule 92bis.1 and  
Administrative Instructions, Section 422)

From the INTERNATIONAL BUREAU

To:

WILSON, Mark, B.  
Fulbright & Jaworski L.L.P.  
600 Congress Avenue  
Suite 2400  
Austin, TX 78701  
ETATS-UNIS D'AMERIQUE

<b>Date of mailing (day/month/year)</b> 31 January 2001 (31.01.01)	<b>IMPORTANT NOTIFICATION</b>
<b>Applicant's or agent's file reference</b> UTFK336P	
<b>International application No.</b> PCT/US99/30707	<b>International filing date (day/month/year)</b> 22 December 1999 (22.12.99)

1. The following indications appeared on record concerning:		
<input checked="" type="checkbox"/> the applicant	<input checked="" type="checkbox"/> the inventor	<input type="checkbox"/> the agent <input type="checkbox"/> the common representative
Name and Address	State of Nationality	State of Residence
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	
2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:		
<input checked="" type="checkbox"/> the person	<input type="checkbox"/> the name	<input type="checkbox"/> the address <input type="checkbox"/> the nationality <input type="checkbox"/> the residence
Name and Address LI, Huiying 384 Falling Star Irvine, CA 92614 United States of America	State of Nationality CN	State of Residence US
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	
3. Further observations, if necessary: <b>Additional applicant and inventor for US only.</b>		
4. A copy of this notification has been sent to:		
<input checked="" type="checkbox"/> the receiving Office	<input type="checkbox"/> the designated Offices concerned	
<input type="checkbox"/> the International Searching Authority	<input checked="" type="checkbox"/> the elected Offices concerned	
<input checked="" type="checkbox"/> the International Preliminary Examining Authority	<input type="checkbox"/> other:	

<b>The International Bureau of WIPO</b> 34, chemin des Colombettes 1211 Geneva 20, Switzerland	<b>Authorized officer</b> C. Cupello
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38



## PATENT COOPERATION TREATY

PCT

NOTIFICATION OF THE RECORDING  
OF A CHANGE(PCT Rule 92bis.1 and  
Administrative Instructions, Section 422)

From the INTERNATIONAL BUREAU

To:

WILSON, Mark, B.  
Fulbright & Jaworski L.L.P.  
600 Congress Avenue  
Suite 2400  
Austin, TX 78701  
ETATS-UNIS D'AMERIQUE

Date of mailing (day/month/year) 14 June 2000 (14.06.00)	<b>IMPORTANT NOTIFICATION</b>
Applicant's or agent's file reference UTFK336P	
International application No. PCT/US99/30707	International filing date (day/month/year) 22 December 1999 (22.12.99)

1. The following indications appeared on record concerning:		
<input checked="" type="checkbox"/> the applicant	<input checked="" type="checkbox"/> the inventor	<input type="checkbox"/> the agent <input type="checkbox"/> the common representative
Name and Address KRAL, Vladimir	State of Nationality **	State of Residence **
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	
2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:		
<input type="checkbox"/> the person	<input type="checkbox"/> the name	<input checked="" type="checkbox"/> the address <input checked="" type="checkbox"/> the nationality <input checked="" type="checkbox"/> the residence
Name and Address KRAL, Vladimir Na Kozacce 8/9275 120 00 Praha 1 Czech Republic	State of Nationality CZ	State of Residence CZ
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	
3. Further observations, if necessary:		
4. A copy of this notification has been sent to:		
<input checked="" type="checkbox"/> the receiving Office	<input type="checkbox"/> the designated Offices concerned	
<input type="checkbox"/> the International Searching Authority	<input type="checkbox"/> the elected Offices concerned	
<input type="checkbox"/> the International Preliminary Examining Authority	<input type="checkbox"/> other:	

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland  Facsimile No.: (41-22) 740.14.35	Authorized officer S. De Michiel  Telephone No.: (41-22) 338.83.38
---	---

## PATENT COOPERATION TREATY

PCT

NOTIFICATION OF THE RECORDING  
OF A CHANGE(PCT Rule 92bis.1 and  
Administrative Instructions, Section 422)

From the INTERNATIONAL BUREAU

To:

WILSON, Mark, B.  
Fulbright & Jaworski L.L.P.  
600 Congress Avenue  
Suite 2400  
Austin, TX 78701  
ETATS-UNIS D'AMERIQUE

Date of mailing (day/month/year) 14 June 2000 (14.06.00)	<b>IMPORTANT NOTIFICATION</b>
Applicant's or agent's file reference UTFK336P	
International application No. PCT/US99/30707	International filing date (day/month/year) 22 December 1999 (22.12.99)

1. The following indications appeared on record concerning:

☒ the applicant      ☒ the inventor      ☐ the agent      ☐ the common representative

Name and Address MARTASEK, Pavel	State of Nationality **	State of Residence **
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☐ the person      ☐ the name      ☒ the address      ☒ the nationality      ☒ the residence

Name and Address MARTASEK, Pavel 7531 Pipers Lane San Antonio, TX 78251 United States of America	State of Nationality CZ	State of Residence US
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

☒ the receiving Office      ☐ the designated Offices concerned  
☐ the International Searching Authority      ☐ the elected Offices concerned  
☐ the International Preliminary Examining Authority      ☐ other:

<p>The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland</p> <p>Facsimile No.: (41-22) 740.14.35</p>	<p>Authorized officer S. De Michiel</p> <p>Telephone No.: (41-22) 338.83.38</p>
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# PCT COOPERATION TRADING JACKETING REQUIRED

## PCT

### NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and  
Administrative Instructions, Section 422)

From the INTERNATIONAL BUREAU

To:

WILSON, Mark, B.  
Fulbright & Jaworski L.L.P.  
600 Congress Avenue  
Suite 2400  
Austin, TX 78701  
ETATS-UNIS D'AMERIQUE

<b>Date of mailing (day/month/year)</b> 31 January 2001 (31.01.01)	
<b>Applicant's or agent's file reference</b> UTFK336P	<b>IMPORTANT NOTIFICATION</b>
<b>International application No.</b> PCT/US99/30707	<b>International filing date (day/month/year)</b> 22 December 1999 (22.12.99)

<b>1. The following indications appeared on record concerning:</b> <input checked="" type="checkbox"/> the applicant <input checked="" type="checkbox"/> the inventor <input type="checkbox"/> the agent <input type="checkbox"/> the common representative									
<b>Name and Address</b>  <div style="text-align: center; font-weight: bold; font-size: 1.2em;">           RECEIVED F &amp; J AUSTIN INTL FEB 13 2001         </div>	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="padding: 2px;">State of Nationality</td> <td style="padding: 2px;">State of Residence</td> </tr> <tr> <td colspan="2" style="padding: 2px;">Telephone No.</td> </tr> <tr> <td colspan="2" style="padding: 2px;">Facsimile No.</td> </tr> <tr> <td colspan="2" style="padding: 2px;">Teleprinter No.</td> </tr> </table>	State of Nationality	State of Residence	Telephone No.		Facsimile No.		Teleprinter No.	
State of Nationality	State of Residence								
Telephone No.									
Facsimile No.									
Teleprinter No.									
<b>2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:</b> <input checked="" type="checkbox"/> the person <input type="checkbox"/> the name <input type="checkbox"/> the address <input type="checkbox"/> the nationality <input type="checkbox"/> the residence									
<b>Name and Address</b> LI, Huiying 384 Falling Star Irvine, CA 92614 United States of America	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="padding: 2px;">State of Nationality CN</td> <td style="padding: 2px;">State of Residence US</td> </tr> <tr> <td colspan="2" style="padding: 2px;">Telephone No.</td> </tr> <tr> <td colspan="2" style="padding: 2px;">Facsimile No.</td> </tr> <tr> <td colspan="2" style="padding: 2px;">Teleprinter No.</td> </tr> </table>	State of Nationality CN	State of Residence US	Telephone No.		Facsimile No.		Teleprinter No.	
State of Nationality CN	State of Residence US								
Telephone No.									
Facsimile No.									
Teleprinter No.									
<b>3. Further observations, if necessary:</b> <b>Additional applicant and inventor for US only.</b>									
<b>4. A copy of this notification has been sent to:</b> <table style="width: 100%;"> <tr> <td><input checked="" type="checkbox"/> the receiving Office</td> <td><input type="checkbox"/> the designated Offices concerned</td> </tr> <tr> <td><input type="checkbox"/> the International Searching Authority</td> <td><input checked="" type="checkbox"/> the elected Offices concerned</td> </tr> <tr> <td><input checked="" type="checkbox"/> the International Preliminary Examining Authority</td> <td><input type="checkbox"/> other:</td> </tr> </table>		<input checked="" type="checkbox"/> the receiving Office	<input type="checkbox"/> the designated Offices concerned	<input type="checkbox"/> the International Searching Authority	<input checked="" type="checkbox"/> the elected Offices concerned	<input checked="" type="checkbox"/> the International Preliminary Examining Authority	<input type="checkbox"/> other:		
<input checked="" type="checkbox"/> the receiving Office	<input type="checkbox"/> the designated Offices concerned								
<input type="checkbox"/> the International Searching Authority	<input checked="" type="checkbox"/> the elected Offices concerned								
<input checked="" type="checkbox"/> the International Preliminary Examining Authority	<input type="checkbox"/> other:								

<p style="text-align: center;">The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland</p> <p>Facsimile No.: (41-22) 740.14.35</p>	<p>Authorized officer</p> <p style="text-align: center;">C. Cupello </p> <p>Telephone No.: (41-22) 338.83.38</p>
--	--

*Pub. data entered*  
**DOCKETED**  
*Pub. data entered*  
**DATE**  
*Pub. data entered*  
**INITIALS**  
*Pub. data entered*  
**PCT**

# PATENT COOPERATION TREATY

*FIK - WIM - NAK - STW*

From the INTERNATIONAL BUREAU

## NOTICE INFORMING THE APPLICANT OF THE COMMUNICATION OF THE INTERNATIONAL APPLICATION TO THE DESIGNATED OFFICES

(PCT Rule 47.1(c), first sentence)

To:

WILSON, Mark, B.  
Fulbright & Jaworski L.L.P.  
600 Congress Avenue  
Suite 2400  
Austin, TX 78701  
ETATS-UNIS D'AMERIQUE

Date of mailing (day/month/year) 29 June 2000 (29.06.00)		<b>IMPORTANT NOTICE</b>	
Applicant's or agent's file reference UTFK336P			
International application No. PCT/US99/30707	International filing date (day/month/year) 22 December 1999 (22.12.99)	Priority date (day/month/year) 22 December 1998 (22.12.98)	
Applicant BOARD OF REGENTS, THE UNIVERSITY OF TEXAS SYSTEM et al			

1. Notice is hereby given that the International Bureau has communicated, as provided in Article 20, the international application to the following designated Offices on the date indicated above as the date of mailing of this Notice:  
AU,CN,JP,KP,KR,US

In accordance with Rule 47.1(c), third sentence, those Offices will accept the present Notice as conclusive evidence that the communication of the international application has duly taken place on the date of mailing indicated above and no copy of the international application is required to be furnished by the applicant to the designated Office(s).

2. The following designated Offices have waived the requirement for such a communication at this time:  
AE,AL,AM,AP,AT,AZ,BA,BB,BG,BR,BY,CA,CH,CR,CU,CZ,DE,DK,DM,EA,EE,EP,ES,FI,GB,GD,GE,GH,GM,HR,HU,ID,IL,IN,IS,KE,KG,KZ,LC,LK,LR,LS,LT,LU,LV,MA,MD,MG,MK,MN,MW,MX,NO,NZ,OA,PL,PT,RO,RU,SD,SE,SG,SI,SK,SL,TJ,TM,TR,TT,TZ,UA,UG,UZ,VN,YU,ZA,ZW  
The communication will be made to those Offices only upon their request. Furthermore, those Offices do not require the applicant to furnish a copy of the international application (Rule 49.1(a-bis)).
3. Enclosed with this Notice is a copy of the international application as published by the International Bureau on 29 June 2000 (29.06.00) under No. WO 00/37653

### REMINDER REGARDING CHAPTER II (Article 31(2)(a) and Rule 54.2)

If the applicant wishes to postpone entry into the national phase until 30 months (or later in some Offices) from the priority date, a demand for international preliminary examination must be filed with the competent International Preliminary Examining Authority before the expiration of 19 months from the priority date.

It is the applicant's sole responsibility to monitor the 19-month time limit.

Note that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination.

### REMINDER REGARDING ENTRY INTO THE NATIONAL PHASE (Article 22 or 39(1))

If the applicant wishes to proceed with the international application in the national phase, he must, within 20 months or 30 months, or later in some Offices, perform the acts referred to therein before each designated or elected Office.

For further important information on the time limits and acts to be performed for entering the national phase, see the Annex to Form PCT/IB/301 (Notification of Receipt of Record Copy) and Volume II of the PCT Applicant's Guide.

**RECEIVED**  
**F & J**  
**AUSTIN INTL**

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No. (41-22) 740.14.35	Authorized officer J. Zahra Telephone No. (41-22) 338.83.38	JUN 20 2000
--	---	-------------

## PATENT COOPERATION TREATY

PCT

INFORMATION CONCERNING ELECTED  
OFFICES NOTIFIED OF THEIR ELECTION

(PCT Rule 61.3)

From the INTERNATIONAL BUREAU

To:

WILSON, Mark, B.  
Fulbright & Jaworski L.L.P.  
600 Congress Avenue  
Suite 2400  
Austin, TX 78701  
ETATS-UNIS D'AMERIQUE

**RECEIVED**  
F & J  
AUSTIN INTL  
JAN 29 2001

Date of mailing (day/month/year) 15 January 2001 (15.01.01)		
Applicant's or agent's file reference UTFK336P		IMPORTANT INFORMATION
International application No. PCT/US99/30707	International filing date (day/month/year) 22 December 1999 (22.12.99)	Priority date (day/month/year) 22 December 1998 (22.12.98)
Applicant BOARD OF REGENTS, THE UNIVERSITY OF TEXAS SYSTEM et al		

1. The applicant is hereby informed that the International Bureau has, according to Article 31(7), notified each of the following Offices of its election:

AP : GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW

EP : AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE

National : AU, BG, CA, CN, CZ, DE, IL, JP, KP, KR, MN, NO, NZ, PL, RO, RU, SE, SK, US

2. The following Offices have waived the requirement for the notification of their election; the notification will be sent to them by the International Bureau only upon their request:

EA : AM, AZ, BY, KG, KZ, MD, RU, TJ, TM

OA : BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG

National : AE, AL, AM, AT, AZ, BA, BB, BR, BY, CH, CR, CU, DK, DM, EE, ES, FI, GB, GD, GE, GH,  
GM, HR, HU, ID, IN, IS, KE, KG, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MW, MX, PT, SD,  
SG, SI, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW

3. The applicant is reminded that he must enter the "national phase" before the expiration of 30 months from the priority date before each of the Offices listed above. This must be done by paying the national fee(s) and furnishing, if prescribed, a translation of the international application (Article 39(1)(a)), as well as, where applicable, by furnishing a translation of any annexes of the international preliminary examination report (Article 36(3)(b) and Rule 74.1).

Some offices have fixed time limits expiring later than the above-mentioned time limit. For detailed information about the applicable time limits and the acts to be performed upon entry into the national phase before a particular Office, see Volume II of the PCT Applicant's Guide.

The entry into the European regional phase is postponed until 31 months from the priority date for all States designated for the purposes of obtaining a European patent.

RECEIVED  
NO DOCKETING REQUIRED

JAN 26 2001

Client:

Attorney(s):

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